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Czech Technical University in Prague

Faculty of Information Technology

Department of Software Engineering

Master's thesis

Business Process Modeling and Simulation: DEMO, BORM and BPMN

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Declaration

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Abstract

This thesis deals with Business Process Modeling and Simulation - the two most important parts in the Business Process Management lifecycle (BPM). Currently, the BPM is a popular management-oriented concept focusing on analyzing an organization as a set of business processes. The number of available process modeling methods and methodologies is very large and the right choice is a crucial prerequisite to success of projects.

In this thesis, the focus is on BORM (Business Object Relationship Modelling), BPMN (Business Process Model and Notation) and DEMO (Design and Engineering Methodology for Organizations). Their advantages and strengths are analyzed and a recommendation of applicability of each is proposed in relation to identified purposes and usage of process modeling. Furthermore, they are assessed in how they support simulation, which plays an important role in the BPM projects, since it allows to conduct a performance analysis and to visualize the process flow and thus helps validate the process. The methodologies are very different, yet they should not be regarded as competitive approaches – on the contrary, in some ways, they may complement each other.

The DEMO methodology does not support simulation, which is considered as its drawback. Therefore, a part of this thesis is dedicated to developing a method of translating the DEMO model into a Petri net simulation model, the latter one having proved to be suitable for simulating workflows. The basis of the method contains an analysis of information needed to build a Petri net model. The method itself constitutes a set of modeling constructs. The created Petri net model can be applied to visualizing the process flow as well as to the performance analysis.

Keywords Business Process Management, Business Process Modeling, Business Process Simulation, DEMO, BORM, BPMN, Petri Net

Abstrakt

Tato práce se zabývá modelováním a simulací byznys procesů, jakožto dvou stěžejních disciplín procesního řízení, které se v současné době stává velmi rozšířenou a populární disciplínou snažící se o zefektivnění procesů organizace. Množství dostupných metodik pro modelování i simulaci procesů je velmi vysoké a výběr správné metodiky je klíčovým pro úspěch projektů.

Práce se zaměřuje na metodiku BORM a DEMO, a notaci BPMN, analyzuje jejich výhody a silné stránky a v návaznosti na analýzu účelů a použití procesního modelování shrnuje doporučení pro využití každé z nich. Protože simulace zvyšuje úspěch projektů procesního modelování, a to zejména tím, že umožňuje kromě typicky používané analýzy výkonnosti taktéž vizualizaci toků v procesu, jsou metodiky hodnoceny i z hlediska podpory simulace procesů. Metodika DEMO je velmi odlišná od metodiky BORM a od BPMN, proto může v některých oblastech být používána pro jejich doplnění.

Metodika DEMO, na rozdíl od metodiky BORM a notace BPMN, nepodporuje simulaci, což je považováno za její nevýhodu. Z tohoto důvodu se část práce zabývá metodou pro překlad DEMO modelu do modelu Petriho sítě – techniky prokázané jako vhodná pro simulaci procesů. Základem metody je analýza elementů a informací potřebných pro vytvoření simulačního modelu. Metoda se skládá ze sady situací (vzorů) namodelovaných pomocí DEMO metodiky a jim odpovídajících modelů Petriho sítě. Výsledný model v Petriho síti má uplatnění pro oba typy simulace, umožňuje vizualizaci toku procesu i přidání výkonnostních atributů a následně analýzu procesů za účelem jejich optimalizace.

Klíčová slova Modelování byznys procesů, simulace byznys procesů, procesní řízení, DEMO metodika, BORM metodika, BPMN, Petriho sítě

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Introduction

Background

Disciplines dealing with processes have been known for many years, but it is especially over the past two decades that they have attracted more attention [59], partly because of the advancements in the Information and Communication Technology. The Information Technology has started to play a more significant role in the organizational management and plays a role of enabler for many process disciplines, like the currently widely known Business Process Management (BPM).

The BPM is a management oriented concept, which, among other techniques, includes Business Process Modeling and Business Process Simulation. Business Process Modeling focuses on depicting organizational business processes for various purposes, which may range from process documentation, through process simulation and optimizing, to requirements specification, software engineering and implementation of process oriented information systems. Only modeling may not reveal sufficient information about the process [14], therefore should be complemented with simulation for a thorough analysis and study of business processes.

Simulation area has been used for analysis of processes since the 1970s [88]. Because business processes are complex, simulation seems to be a suitable method for business process (re)engineering, (re)design and similar activities.

The number of available process modeling or re-engineering methods and methodologies is very large and is still increasing. Kettinger et al. [52] surveyed 25 methodologies, 72 techniques and 102 tools for process modeling, and these numbers are not expected to have decreased today. The processes may be modeled from diverse perspectives; each methodology was developed to serve a slightly different purpose and is expected to bring various benefits. Comparing, or even searching for all available Business Process Modeling methodologies, would be too extensive research, which would not even bring as much of a value - it is more important to know how and in which situation to use each. Therefore, this thesis focuses on three particular ones, namely: *DEMO (Design and Engineering Methodology for Organizations), BORM (Business Object Relationship Modelling)* and *BPMN (Business Process Model and Notation).*

The BORM methodology is an object-oriented and process-based analysis and design methodology, which in its first stage focuses on capturing the organizational processes [82], by which it aims at covering the gap between the Business Engineering and Software Engineering. The BPMN is a world-wide known standard that defines notation for business process models. It has a wide application, as it captures the operational details of the process. Finally, the DEMO is a methodology for (re)designing and (re)engineering organizations (laid down by Dietz [32]), that presents a systematic way of developing the ontology of an enterprise. It reveals both the construction and operation of an organization.

Although the BORM methodology, the BPMN and the DEMO methodology are very different, have been developed in a different time, for a different purpose and capture processes from a different perspective, they all focus on modeling business processes. Therefore, their comparison seems particularly attractive. Furthermore, when unified, they cover more aspects of organizational processes modeling: due to their differences, they complement each other in some ways rather than compete with each other.

Goal and research questions

The main goal of this thesis is to compare the BORM methodology, the BPMN and the DEMO methodology in relation to the application and to the purpose of Business Process Modeling in an organization and to compare applicability of each methodology in relation to the organizational management levels. The DEMO methodology presents a systematic way of developing the ontological model of an enterprise and is suitable for modeling complex business processes. However in order to get a thorough insight into the system's behavior, modeling should be complemented with simulation. The drawback of the DEMO methodology is in its inability to simulate the created model. The second goal of this thesis, therefore, is to propose a method of translating the DEMO model into a (high-level) Petri net simulation model. The Petri net was chosen because it is a technique which proved suitable for simulating workflows. Based on the goals of the thesis, two main research questions were determined:

1. What are the advantages and strengths of the BORM methodology, the BPMN and the DEMO methodology and which one would be applicable for which purposes of process modeling?
2. How to translate the DEMO model into a (high-level) Petri net simulation model?

Approach

Answering the first question consists of three steps. Firstly, the Business Process Modeling benefits, purpose, application and perspectives of process modeling are summarized based on a literature search. Then the BORM and DEMO methodologies and the BPMN are described in detail. Finally, they are evaluated based on findings from the first step. To complement the theoretical findings, the aspects are shown on a case study.

In order to answer the second question, firstly, information included in the DEMO's aspect models and information needed to build a simulation model and to perform a simulation in a (high-level) Petri net is analyzed based on a literature search. According to that is stated what is included in the DEMO model and what would require further specification when constructing a simulation model. The method of translating the DEMO model into a Petri net simulation model is created and verified based on multiple case studies of various type and complexity.

The work was completed using software tools: Visio 2010 [72] and SmartDraw 2012 [92] for figures; Xemod [73], Bizagi [19], IzmanCASE [76] and CPN Tools [28] for process' modeling; LaTeX [1] for formating this document.

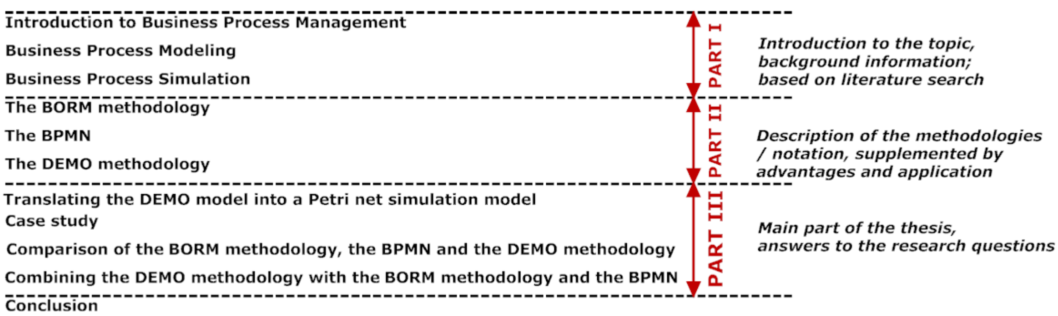
The structure of the thesis

The thesis is divided into three parts, as shown in a figure bellow. The terms are either defined when used for the first time, or in the Appendix B. The list of acronyms is provided in Appendix A. Most chapters contain a brief summary at the end.

First three chapters provide some background information needed to gain understanding of the topic, and are based on a literature search. Chapter 1 covers introduction into the Business Process Management, defines necessary terms and presents an insight into the history of process oriented disciplines. Chapter 2 describes various viewpoints on Business Process Modeling, provides an overview of purposes and perspectives of process modeling, perceived benefits and application of process modeling in relation to organizational management levels. It lays down a theoretical background, which is further used when comparing the DEMO, BORM and BPMN. Similarly, Chapter 3 provides an insight into the Business Process Simulation, points out its importance, application and process of building a simulation model.

Chapters 4, 5 and 6 include description of the BORM methodology, the BPMN and the DEMO methodology. Besides the pure description of the concepts and aspect models, the chapters are supplemented with additional information, like the motivation and intended purpose of the methodologies, their application and advantages, as described by the authors or perceived by the professionalsusers.

The rest of the thesis includes the main contributions and answers to the research questions. Chapter 7 describes a developed method for translating the DEMO model into a Petri net simulation model. Chapter 8 presents a case example of a small organization with three identified business processes, which are modeled in the BORM, BPMN and DEMO. In addition to that, a simulation model in a Petri net is created according to the developed method. Chapter 9 compares the BORM and DEMO methodologies and the BPMN in three different ways. It is concluded with recommendations for choosing a process modeling methodology and with assessing suitability of each of the three for different levels of organizational management. Because the BORM and DEMO methodologies and the BPMN are very different, an option how the DEMO methodology may be used together with the BORM methodology and the BPMN is very briefly discussed in Chapter 10, even though it has not been initially included in the assignment of the thesis. In Chapter 11, the work is concluded and summarized.



Chapter 1

Introduction to Business Process Management

Business Process Modeling (BPMo) and *Business Process Simulation (BPS)* are part of a discipline called *Business Process Management (BPM)*. But besides modeling and simulation, there are plenty of other terms used in regards to business processes, like *Business Process Re-engineering (BPR)*, *Business Process Analysis (BPA)*, *Workflow Management (WfM)* and others. Therefore, **the aim of this chapter is to define the terms, describe Business Process Management and a relation of Business Process Modeling and Simulation to Business Process Management**.

The disciplines dealing with processes have been getting more attention only over the past two decades, but the ideas leading to process management has been known for many years. The increasing attention to business process disciplines relates to the ongoing effort of organizations to keep and gain a competitive advantage over its rivals, especially in nowadays highly competitive and often saturated market and demanding society, where time, cost and customer satisfaction play a key role in gaining or losing a business. The desire to increase efficiency in production has been increasing over the years, and is reflected by the focus of the organizations. As summarized by Lindsay et al. [59], in the '60s the industry concentrated on how to produce more (on quantity), in the '70s on how to produce cheaper (cost), in the '80s on how to produce better (quality), in the '90s on how to produce quicker (lead time) and in the 21st century, the focus is on how to offer more (service).

To put the industry focus in relation to process management, we have to go back to '70s. According to Snabe et al. [93] the foundation of a process management can be traced back to Adam Smith, who sees an effective division of labor a key to increase productivity. Next stage is evolution of the *scientific management*, initiated by Taylor in the '80s and '90s. Perhaps the most pervasive business concept of all times is the *Total Quality Management (TQM)*, which is a management strategy aimed at embedding awareness of quality in all organizational processes. The quality cycle, sometimes known as *PDCA*, which is very popular in process disciplines up to nowadays, has 4 stages: ***Plan - Do - Check - Act***, as displayed in figure 1.1.

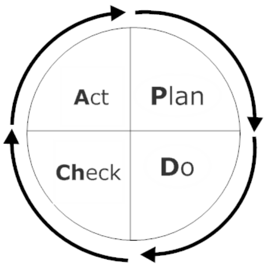


Figure 1.1: Quality lifecycle: Plan - Do - Check - Act

The TQM was used in approaches like *Lean Manufacturing* or *Business Excellence*, which both focus on business improvement and management, and *Six Sigma*, which is a quality-focused process management concept based on statistics [93]. In the '80s and early '90s Business Process Reengineering, which is known for its radical change in processes, started to be popular, followed by Workflow Management in the '90s [56].Currently the most known and widely spread out term is Business Process Management (BPM). Although the BPM has focused on automation and technology in the past, the concept is gradually becoming more and more of a management oriented concept [93]. Business Process Management involves business process defining, modeling, simulation, deploying, executing, monitoring, analyzing and optimizing, as displayed in figure 1.2.

With the increasing advancements in Information and Communication Technologies, the ICT has started to play more significant role in an organizational management. It plays a key role in Business Process Re-engineering, but can also be beneficial in TQM, automation or restructuring [37]. The changes may be IT-led or IT-enabled [65]. Each of the disciplines named within the BPM is supported by the ICT, and some of those, like execution and simulation would not be possible without it.

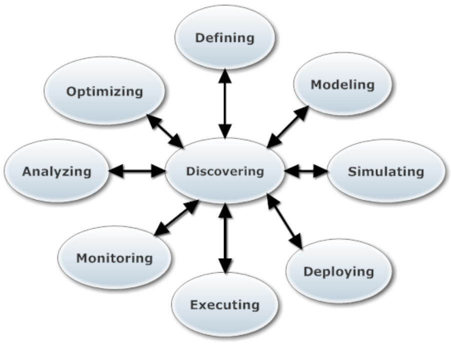


Figure 1.2: Area of Business Process Management

Sometimes, Business Process Management is considered a synonym for Business Process Re-engineering [59], sometimes as a “next step” after Workflow Management wave [4]. The industry focus, described above, corresponds to evolution of process-oriented disciplines, which is displayed in figure 1.3. It shows when each of the disciplines emerged. As it is possible to see, Business Process Management is the newest one, yet the other terms are sometimes still used. The quality lifecycle (the P-D-C-A concept), which emerged as a part of the TQM, is still used for process improvement. Relation of BPR, WfM and BPM is described after each of these terms is defined.

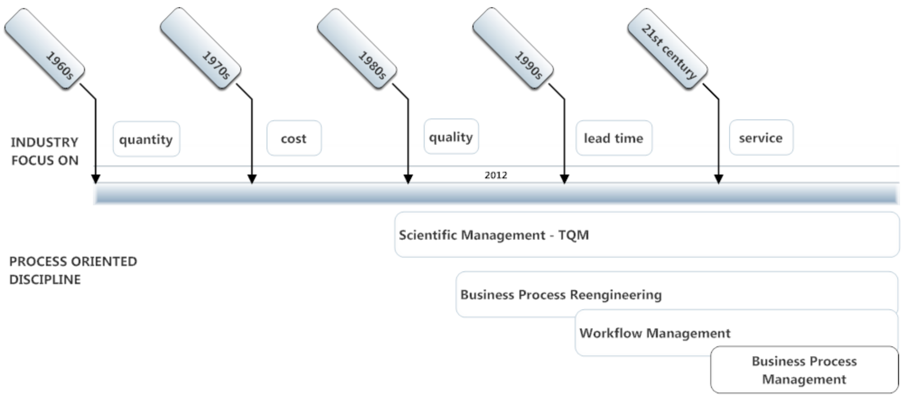


Figure 1.3: Historical evolution of Business Process Management

1.1 Workflow

The Workflow Management Coalition [101] defines workflow as:

The automation of a business process, in whole or part, during which documents, information or tasks are passed from one participant to another for action, according to a set of procedural rules.

Workflow is a term very close to a business process. According to the definition workflow is automation of business process. It is however important to mention, that workflow might not cover the whole business process, but only its part. The relation is displayed in figure 1.4.

1.2 Business Process

There are nearly as many definitions of a business process, as a number of papers or books talking about them [65]. Not to take too much space, only 3 definitions are included:

A Business Process can be described as a set of activities that are being executed according to certain rules with respect to certain objectives. Depending on the modeling objectives, functional (concentrating only on activities and their order) or organizational (including the organizational context in which activities are to be carried out) aspects can be emphasized [31].

A business process is a collection of activities that takes one or more kinds of input and creates an output that is of value to the customer. [43]

A business process is an ordering of work activities across time and place, with a beginning, an end, and clearly identified inputs and outputs. [30]

Some authors emphasize, that a business process must produce something that is of value to the customer, others see the essence of a business process in the order of the activities. In addition to the definitions of a business process, some sources distinguish the term **process** from the term **business process**. Voříšek et al. [97] defines ***process*** as a *purposely planned and realized activity, in which inputs are transformed into outputs, with a help of necessary sources* and ***business process*** according to him is a *process that helps the organization to achieve its goals and ensures production of planned outcomes (products, services).*

Similarly, as with the huge amount of definitions, there are various ways of categorizing processes. The two most common classifications are **process maturity** and **process type**.

The original **process maturity** levels defined by Macintosh [61] classify processes as ***initial, repeatable, defined, managed*** and ***optimized***. Some sources like Voříšek et al. [97] or Řepa [37] define six levels of process maturity, where the first level is ***non-existing*** process, and then the other five levels follow.

The division of processes according to their **type and purpose** has also different viewpoints. Lindsay et.al [59], summarizes three perspectives on the process division - *production vs. coordination; processes that are executed on machine vs. processes that are executed by human; material vs. information vs. business processes.* According to Voříšek et al. [97] processes may be core, control and support. Similarly, Melão [65] divides them into *core*, *support* and *management.* The last two divisions are quite similar. ***Core processes*** have external customers and include primary activities of the value chain. They add value to the company. ***Support processes*** have internal customers and concern secondary activities in the value chain. ***Management processes*** manage core and support processes. ***ICT processes*** are usually regarded support processes, but some of them can also be classified as core processes.

As we can see, the classification of processes and even the definitions are not unequivocal. All definitions have a similar meaning, and by term business process in this thesis is meant *a sequence of activities, at organizational or inter-organizational level, that leads from an input to a desired output.*

A business process is displayed in figure 1.4, where also the relation of a *business process* and *workflow* is visible.

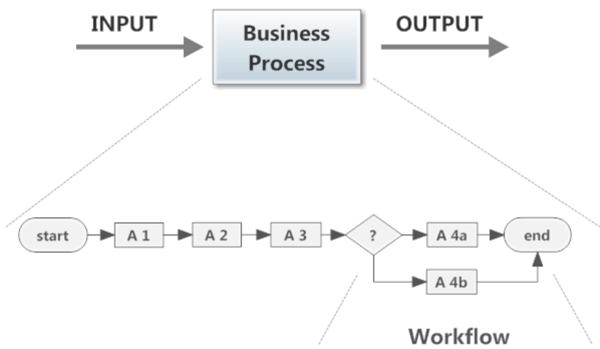


Figure 1.4: Business Process and Workflow

1.3 Workflow management

According to the *Workflow Management Coalition* [101] a ***Workflow Management System (WfMS)*** is defined as:

A system that defines, creates and manages the execution of workflows through the use of software, running on one or more workflow engines, which is able to interpret the process definition, interact with workflow participants and, where required, invoke the use of IT tools and applications.

Workflow management (WfM) then deals with *creating and managing the execution of workflows.*

It is clear from both definitions, that workflow has something to do with the actual execution, or automation, of business processes, which could be done with or without a help of software.

1.4 Business Process Re-engineering

BPR is an ambiguous abbreviation, which can stand either for *Business Process Re-engineering*, or for *Business Process Redesign*, however more often stands for *Re-engineering.*

Business Process Re-engineering involves radical redesign of business processes with the aim of producing equally radical improvements in performance [102].

Business Process Redesign aims at radical redesign of business processes to achieve dramatic improvements in critical, contemporary measures of performance, such as cost, quality, service and speed. [43]).

As is explained by Zairi and Sinclair [102], there are even more terms used in the literature, then just *Business Process Re-engineering* and *Business Process Redesign.* In addition to these, some authors use terms like *core process design* or *business restructuring.* All of these concepts cover a continuum of **activities ranging from the continuous improvement of processes to the complete restructuring of organizations**. They have in common the concept of processes and the need to improve their performance and differ by the level of magnitude [102].

Different sources describe BPR differently, namely with a different level of radicality. According to Melão and Pidd [65], BPR can be: *novel vs. established; radical vs. incremental; clean slate vs. existing process; broad vs. narrow; IT-led vs. IT-enabled; mechanistic vs. holistic; dramatic vs. modest; top-down vs. bottom-up; inspiration vs. methodologically supported.*

First generation re-engineering, which presented BPR as a new, radical, IT-led, mechanistic and inspirational, is evolving into second generation process management, which views BPR as hybrid, contingent, IT-enabled, holistic and systematic. The second generation of *Business Process Re-engineering* is often referred to as *Business Process Management.*

1.5 Business Process Management (BPM)

Aalst et al. [4], a well-known BPM researcher, defines it as:

Supporting business processes using methods, techniques, and software to design, enact, control, and analyze operational processes involving humans, organizations, applications, documents and other sources of information.

Ganesan [39] defines BPM as:

The way business processes are organized and managed so that they are effective to provide competitive advantage in terms of cost, quality, time or flexibility for enterprises so as to fulfill the needs of their customers through product/services. BPM is not limited on information technology enabled workflow management or automation of business processes, but it definitely includes them as well.

Elzinga [36] describes BPM as:

A systematic, structured approach to analyze, improve, control, and manage processes with the aim of improving the quality of products and services.

The definition of Aalst et al. [4] is restricted to **operational processes** - the ones on strategic level are excluded. While he sees BPM as a method of supporting business processes, the other two definitions have the main focus on process improvement, which leads into quality of products or services, as a step to fulfill higher organizational goals, like gaining a competitive advantage. ***BPM is a process-oriented management discipline aided by IT with a goal to organize people for greater agility [55] and manage changes to improve business processes*** [78]. It is enabled as well as supported by the means of technology.

1.5.1 BPM lifecycle

Aalst et al. [4], who views at BPM on the level of operational processes, presents a BPM lifecycle on this level, as displayed in figure 1.5. The lifecycle describes the various phases in support of operational business processes. The figure also displays the relation of *WfM* and *BPM.*

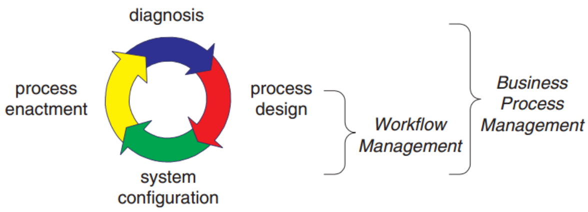


Figure 1.5: Business Process Management Lifecycle [4]

The BPM lifecycle consists of 4 stages [4]:

1. **Process design:** In the design phase, processes are modeled as-is and (re)designed.

2. **System configuration:** In the configuration phase, designs are implemented by configuring a process aware information system. This stage is the hardest one to standardize due to differing IT architectures of each enterprise [55].

3. **Process enactment:** The operational business processes are executed using the system configured.

4. **Diagnosis:** Operational processes are analyzed to identify problems and find out things that can be improved.

It was mentioned in the definition, that BPM is a management discipline. That is why it should not be restricted to operational-level processes only. More detailed BPM lifecycle, displayed in figure 1.6, presents Mercx [66]. Defining the in-scope processes is followed by modeling them. These two steps always remain the same. The rest of the lifecycle steps are not mandatory and depend on the purpose of the project. The processes may be modeled for only the purpose of documenting them, where the rest of the steps are not performed, or they can be optimized or re-designed based on simulation only, or they can be modeled and executed with skipping the simulation step. In all cases, it is important to realize, that **modeling plays a crucial role, and should be done keeping in mind the future application of the process model**. Modeling is in detail discussed in Chapter 2, simulation, as a second crucial step in the lifecycle, in Chapter 3.

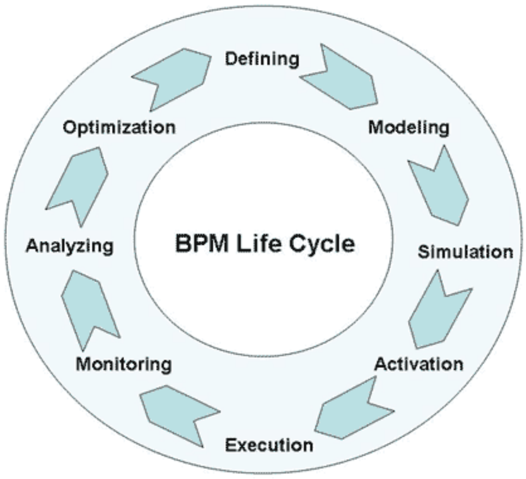


Figure 1.6: Detailed Business Process Management Lifecycle [66]

1.5.2 BPM operational level standards

There is a countless number of methods, methodologies and techniques in BPM, as well as tools to support them. To go over the long lists of those is not a purpose of this thesis, however as they are important, few widely known standards are mentioned. Standardization plays a crucial role in all stages, especially regarding the BPM projects' success and efficiency [99]). Ko et al. [55] divides BPM standards into four types, three of those are dominant in one of the phases of the BPM lifecycle. In the **process design stage**, graphical standards are dominant, in **process enactment stage** execution standards and in **diagnosis stage** diagnosis standards. The fourth type is the interchange standards, which facilitate the portability of data. The categories of current BPM standards in relation to the BPM lifecycle on the operational level are displayed in figure 1.7.

1.5.3 Application of BPM

The BPM may be used at different levels of organizational management, but it is important to keep in mind, that this is not the only way of looking at BPM. It can find application in areas ranging from management strategy to a software system development. To get back to the management levels, according to Bandara et al. [11], the **strategic level** relates to top management support, business and IT alignment, process organization and governance issues. The **tactical level** encompasses challenges

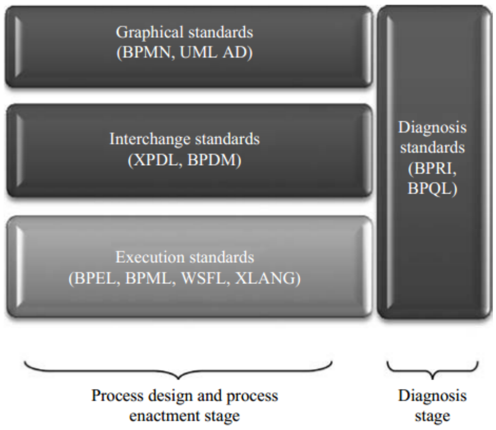


Figure 1.7: BPM standards [55]

in efforts such as process modeling, process performance measurement and BPM methodologies. Finally, the **operational level** relates to technological issues in BPM adoption such as technology capability, SOA maturity in the technology landscape, use of XML and so on. Figure 1.8 displays the application of BPM at different organizational management levels.

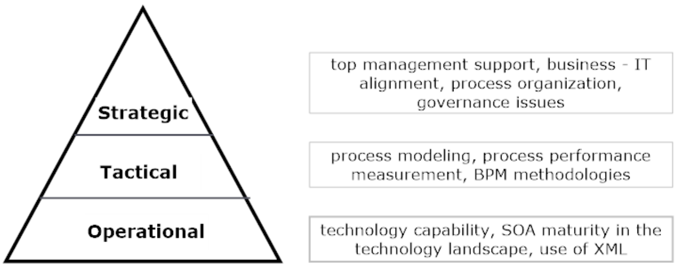


Figure 1.8: Levels of Business Process Modeling benefits

If we look back at the definition of a *business process*, it is important to point out, that a process may cross the whole organization – to be concrete, the *core processes* does, the *control processes* may, but the *support processes* does not. This is important to realize in relation to the organizational structure. The organization may be structured and managed in a ***functional way, matrix way, process way***, or a combination of these, or another (not so often used) ways [64]. In the functional management, the organization is grouped by areas of specialty within different functional areas. In the matrix management, employees are grouped by work assignments (projects), so they belong into two groups at a time – their department and their project group. The BPM handles processes as a horizontal, rather than vertical (or functional). If the processes were viewed at based on functions, they would be isolated, which would cause duplications of tasks, delays etc. [66]. Horizontal processes cross the boundaries of departments and therefore are more complex. The process management, compared to the other management techniques, can make the processes and so the organization working more efficiently.

1.6 BPM vs WfM vs BPR

Three terms – ***Business Process Management (BPM), Business Process Re-engineering (BPR)*** and ***Workflow Management (WfM)*** were defined. Now, lets summarize the differences between them . Workflow Management is historically an older term than currently popular Business Process Management. Often BPM is considered as a "next step" after Workflow Management [99]. This could be also seen in figure 1.3. BPR is older than WfM, yet it is BPM that is considered its successor, not WfM, because it is rarely being put in relation to BPR.

1.6.1 BPM vs WfM

Business Process Management is a process-oriented discipline, not a technology. Workflow management, in comparison to BPM, is a flow management technology that supports BPM [46]. As can be seen from the BPM lifecycle presented by Aalst et al. [4], displayed in figure 1.5, **BPM extends WfM approach by the diagnosis phase.**

1.6.2 BPM vs BPR

Business Process Management and Business Process Re-engineering are in some sources, like Lindsay et al. [59], considered as a synonym. In fact, they have the same goal, which is increasing efficiency and performance of business processes, which is done by analyzing and redesigning them. Both BPR and BPM are based on the notion that a business process is a fundamental element of analysis [65]. The difference, according to Ko et al. [55], is that *Business Process Re-engineering calls for a radical obliteration of existing business processes, while its descendant Business Process Management is more practical, iterative and incremental in fine-tuning business* *processes*. This is confirmed by Mercx [66], who also considers BPR as a bit extreme, compared to incremental BPM.

1.7 Definition of the remaining terms

Not all terms have been defined yet, so a brief summary of the remaining ones, that are either well-known and often used, or needed to be defined for the purpose of this thesis, is provided.

1.7.1 Business Process Analysis (BPA)

Business Process Analysis aims at investigating properties of business processes that are neither obvious nor trivial. It covers simulation and diagnosis, verification and performance analysis [4] [99].

1.7.2 Business Process Modeling (BPMo)

Business Process Modeling aims at depicting the way organizations conduct business processes. The result of Business Process Modeling is a Business Process Model, which is a graphical representation of the process. More detailed definition follows in Chapter 2.

1.7.3 Business Process Simulation (BPS)

Business Process Simulation facilitates process diagnosis in the sense that by simulating real-world cases, domain experts can acknowledge correct modeling or propose modifications of the original process model [4] [99].

1.7.4 Business Process Improvement (BPI)

Business Process Improvement is a methodology that focuses on improving administrative, support and production business processes [44]. It is a systematic approach, with a main goal to optimize processes to achieve results more efficiently.

These terms are related to each other, as well as to the BPM lifecycle. *Business Process Modeling* is a fundamental pre-requisite for organizations wishing to engage in *Business Process Improvement (BPI)* or *Business Process Management (BPM)* initiatives [49]. *BPI* and *BPM* at the same time involve *Business Process Analysis (BPA)*. According to Ganesan [39], *Business Process Modeling* is a first step to *Business Process Analysis*, which is a first step to *Business Process Improvement*.

To position it to the operational-level BPM lifecycle presented by Aalst et al. [4], figure 1.5, *Business Process Analysis* would be a part of **diagnosis phase**, while *Business Process Modeling* is in a close relationship to the **design phase**. *Business Process Design* refers to the overall design process involving multiple steps and *Business Process Modeling* refers to the actual representation of the business process in terms of a business process model using a process language.

Business Process Modeling and Simulation are separate steps in BPM lifecycle presented by Mercx [66], displayed in figure 1.9. *Business Process Analysis* can refer either to the step "analyzing", and may concern performance analysis of the process, or analysis of the process which is done before modeling it. In the first case, the analysis is done based on the results of the simulation or run of the real process, with a goal to optimize it. In the second case, by analyzing the process is meant identification of the process steps, actor roles and other information that we want to capture in the model of the process.

Business Process Improvement is not mentioned in the BPM lifecycle, because rather than a single step in it, it is an approach similar to BPM, with a lower level of complexity. BPI would include all modeling, simulation and analysis, as displayed in figure 1.9.

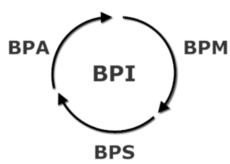


Figure 1.9: Business Process Improvement cycle

1.8 Summary

This chapter provided a brief historical evolution of Business Process Management and defined the terms used within this domain. Not all of the terms will be used later in this thesis, but they are widely known within the BPM and therefore could not have been omitted. Since Business Process Management is a currently used discipline, a successor of Workflow Management and Business Process Re-engineering, for the rest of this thesis the focus remains on the BPM. Business Process Modeling followed by Business Process Simulation are the two initial and core steps in the BPM lifecycle, after defining the project scope, so the main focus in this thesis is paid to them. It is important to keep in mind, that not all steps of BPM lifecycle must necessarily be always performed - this depends on the purpose of the project, but the modeling phase would always be performed, and should be done with respect to the intended usage of the process model, which is in greater detail discussed in Chapter 2.

Chapter **2**

Business Process Modeling

2.1 Introduction

Business Process Modeling is one of the most important steps in the *Business Process Management* lifecycle. It is important to realize the purpose of the model and adjust the modeling to it. **The aim of this chapter is to discuss various viewpoints on process modeling, namely the purpose of process modeling, expected benefits, usage of process modeling and process model, perspectives on process modeling and process modeling techniques.** The chapter lays down the theoretical background within Business Process Modeling, and is important for the rest of this thesis, especially for Chapter 9, that deals with comparison of the BORM methodology, the BPMN and the DEMO methodology.

Business Process Modeling is often known by an abbreviation ***BPM***, which is, like with ***BPR***, an ambiguous abbreviation, that can stand either for ***Business Process Modeling***, or for ***Business Process Management***. To make the distinction, in this thesis is for ***Business Process Management*** used abbreviation ***BPM*** and for ***Business Process Modeling*** abbreviation ***BPMo***.

Business Process Modeling is an approach to depict the way organizations conduct current or future business processes [49].

*Business Process Modeling is a visual representation of the process. It usually utilizes some modeling approach as necessary for the end use of modeling. Modeling involves gathering information about and around business process so that the process can be optimize*d [39].

Sometimes a term *business process mapping* is used. Modeling and mapping definitely are not the same. Mapping is more of a representation of finite details and might or might not be used to analyze the process. It is rather used for a specific purpose of process representation, like to communicate what is happening in the process. Modeling normally involves capturing data, roles, resources and other details, that would be necessary for process simulation [39].

2.1.1 Process Model

When talking about Business Process Modeling, terms *model*, *process model* or *conceptual process model* are often used.

Model is description as well as abstraction of a system [12].

Conceptual model represents the so-called concepts (entities), and relations between them [48].

Process model is a conceptualization of the (business) process in an enterprise [32].

Process model and conceptual process model can be considered as synonyms, because process model is always a conceptual model of a real process.

Process models describe, typically in a graphical way, the activities, events and control flow logic that constitutes a business process [83]. They are considered a key instrument for the analysis and design of process-aware Information systems, organizational documentation and re-engineering, and the design of service oriented architectures [49]. Process models are gained as a result of Business Process Modeling.

2.1.2 Reasons for process modeling

Process modeling is done for numerous reasons, mainly in relation to [56]:

1. Enterprise Modeling
2. Business Process Modeling
3. Information Systems Development

Enterprise modeling is a preliminary stage to Enterprise Engineering, which deals with analysis, design, engineering and implementation of enterprises [86]. Business Process Modeling plays a crucial role in successful (re)engineering of the involved systems, because the first step is considered to be understanding the processes of an organization [48]. Successful system implementation (IS development) starts with an understanding of the business processes of an organization [8]. This is displayed in figure 2.1.

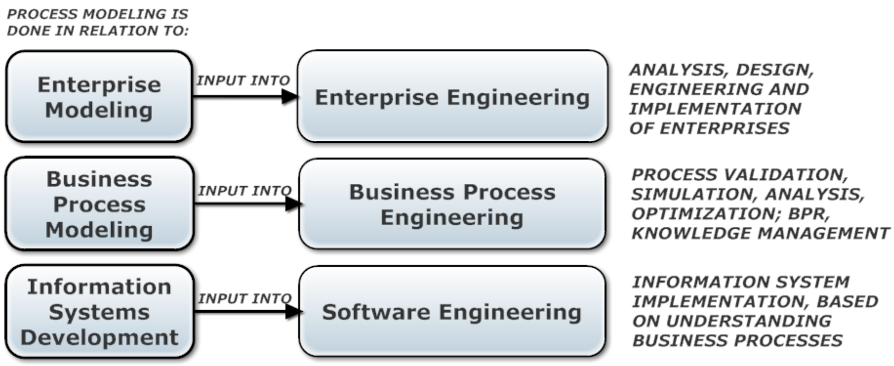


Figure 2.1: Business Process Modeling usage

2.2 Benefits of Business Process Modeling

Looking from the organizational management perspective, Business Process Modeling is beneficial in **strategic** as well as **operational** management. Strategic goals, like customer satisfaction and profit, explain why a certain process should exist in the organization and be driven in a certain way. Analysis of the strategic goals results in the process definition, while operational goals concern instances of processes and their operation [18].

Following extensive summary of process modeling benefits is based on a research conducted among practitioners, vendors and academics. The perceived benefits are classified into 5 categories: ***strategic, organizational, managerial, operational*** and ***IT Infrastructure***. The table 2.1 displays what are the main perceived benefits in each of the category, according to the results of the survey performed by Indulska et al. [49].

According to the survey, most of the benefits lie in the **organizational**, **managerial** and **operational** dimensions and the top three process modeling benefits are **process improvement**, **understanding** and **communication**.

It is important to keep in mind that the categories are not strictly set and one benefit may fall into more than one category, but is listed within the dominant one. At the same time, they are not detached categories, but some relate to each other. As a matter of fact, they can be mapped on the classical management pyramid, which includes ***strategic, tactical*** and ***operational*** levels.

Strategic management involves the analysis of factors associated with business, like customers, competitors etc. The main objective of a strategic

Category	Description	Top benefits in category
Strategic benefits	Benefits from process modeling for strategic activities such as long-range planning, mergers & acquisitions, product planning, customer retention.	Alignment with organizational goals and other strategic perspectives
Organizational benefits	Benefits from process modeling to the organization in terms of strategy execution, learning, cohesion, and increased focus.	Understanding and communication Knowledge Management
Managerial benefits	Benefits from process modeling provided to management in terms of improved decision making and planning.	Process Performance Management Change Management Process Simulation
Operational benefits	Benefits from process modeling related to the reduction of process costs, increase of process productivity, increase of process quality, improved customer service and reduces cost execution time.	Process Improvement Requirements specification Process verification
IT Infrastructure benefits	Benefits from process modeling relating to the IT support of business agility, reduction of IT costs, reduction of implementation time.	Model-driven Process Execution

Table 2.1: Business Process Modeling benefits

management is to achieve better alignment of corporate policies and strategic priorities. Strategic planning focuses on long term vision and goals, it looks at wider picture than the tactical planning, which supports its individual partial objectives [25].

Tactical management and planning involves immediate or short-term actions that are of a lesser importance or magnitude than those on strategic level. The tactical goals and actions also support achieving a strategic plan or objectives [26].

Operational management involves a short-term plan, focused on achieving tactical objectives. It covers the operation of processes, including tasks, resources, etc., with a focus on process optimization, improvement and effectiveness [24].

The **Strategic benefits** of Business Process Modeling support unequivocally the strategic management level, the operational benefits the Operational level. **Managerial benefits**, which are defined as benefits, that improve decision making and planning, support the tactical management and decision making, as that focuses on short-term actions and goals [26]. The **IT Infrastructure benefits** support the operational level, because they include implementation of changes and process execution, which is, what operational management deals with. The IT technology supports and is present in all levels of the organizational management. The last category of benefits are the **Organizational benefits**, which include mainly support of strategy execution, reporting (which could be done for all levels), understanding the processes and communication between entities in the organization, which is also done on all levels. The relation of categories of business process modeling benefits and the three organizational management levels is displayed in figure 2.2.

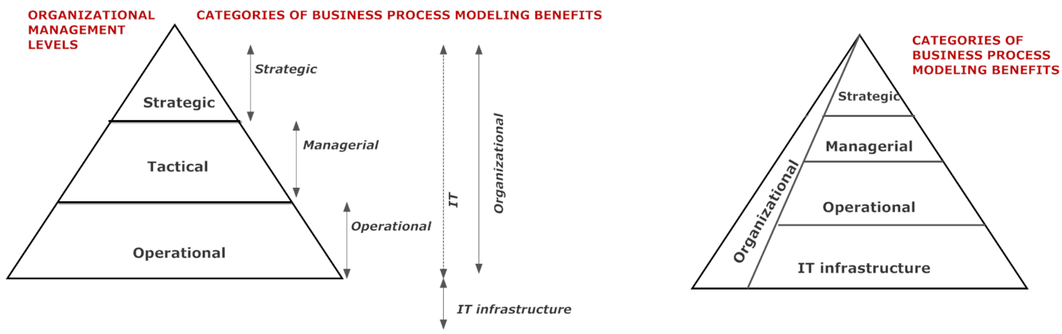


Figure 2.2: Categories of Business Process Modeling benefits

2.3 Purpose and application

The purpose of Business Process Modeling is closely related to its application. In literature, *purpose, application or usage* and even *benefits* are often mixed. ***Purpose*** means why Business Process Modeling is conducted. It is more general than application. ***Application*** or usage of Business Process Modeling, or rather process models, specifies for what exactly the models (or modeling) may be used. ***Benefit*** is something that may or may not be gained as a result of the Business Process Modeling project, depending on its success. Benefits may be seen within different areas of the organization, and different management levels, not necessarily only in the ones directly connected with the project.

For example the purpose of modeling may be to capture the organizational processes. The created process model has application in software development – according to the captured processes, the information system is designed and developed. The main benefit of process modeling in this case may be a system which fully supports the needs of the employees and the organizational processes, and contributes to increase the efficiency.

Business Process Modeling projects are always conducted with respect to the anticipated purpose. In order to choose the right technique, the modeler must know the purpose of the model that will be constructed, as different techniques are suitable for different purposes [8].

Aguilar-Savén [8] created a framework for classifying business process modeling techniques and within that identified **four purposes of business process models**:

1. Descriptive models for learning

2. Descriptive and analytical models for decision support to process development and design

3. Enactable or analytical models for decision support during process execution and control

4. Enactment support models to Information technology

Phalp [81] distinguishes between **three purposes of process modeling**, which are, according to him, closely related to its usage:

1. **Capturing**: It is used for SW development. It focuses on capturing a legible and understandable view of the business process. Users rather observe the model, than interact with it.

2. **Analyzing**: The models should present both dynamic and functional aspects of the process. Normally, users want to interact with the process, like use simulation to be able to answer what-if questions.

3. **Presenting**: The models should be easy to understand, as they are used for documenting the process, so typically using diagrammatic notation is suitable.

Krogstie [56] does not talk about the purpose, but presents a more extensive list of **usage areas of process models**. He sees application in:

1. Human sense-making, which involves description of current state (AS-IS modeling).
2. Communication between people in organization.
3. Computer assisted analysis, which is used to gain knowledge about organization through simulation and comparison of AS-IS state and TO-BE state.
4. Quality assurance, which ensures that the organization acts according to a certified process
5. Model deployment and activation. Models can be activated through people or automatically using workflow systems.
6. Input into traditional development project.

From the above mentioned, Aguilar-Savén [8] talked about purpose of process modeling, Phalp[81] about purpose in relation with usage, and Krogstie [56] about usage of process modeling. Yet all three sources concur in business process models being primarily used either to **learn about process**, to **make decisions about process** or to **develop a supportive software**.

Hommes [48] summarizes areas, where BPMo has an application, and in which therefore are the benefits perceived. The various areas, in which he sees application, are displayed in figure 2.3. Especially interesting from the IT-perspective is the purpose of process modeling for *requirements engineering*. The organizational processes are nowadays supported by the means of technology, and the first step in securing appropriate technological support is understanding the needs of the organization and users. **Requirements engineering is especially helpful for business-IT alignment, information systems development and workflow automation**.

It is interesting to see, how different sources point out different application of business process modeling, but they often mean the same, just use different words. The most general three purposes of process modeling are **capturing, analyzing** and **presenting**. The rest of the mentioned could fall into one of these three categories. The viewpoint of each of the source is displayed in table 2.1 and put in relation to the main three identified categories. Some of the items were pretty straightforward to map, while

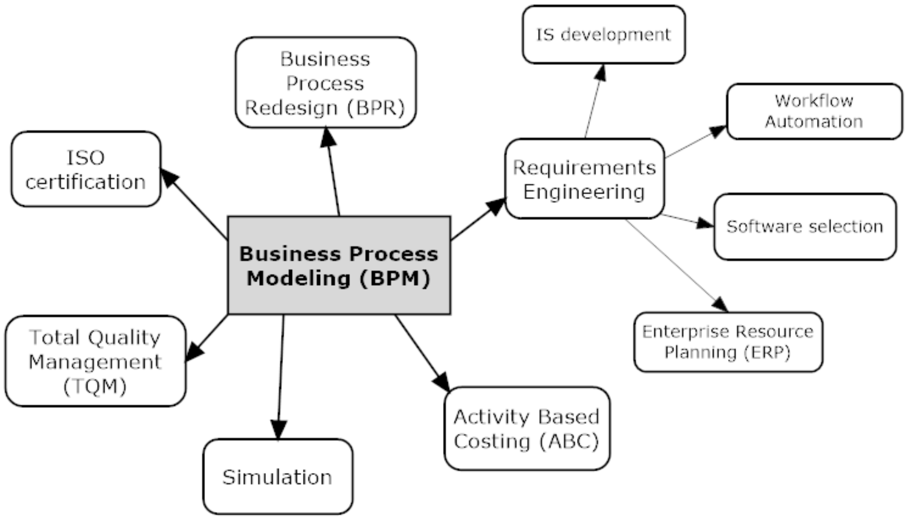


Figure 2.3: Application of Business Process Modeling [48]

others fall on the border of two categories. Those were placed in the predominant one, with a note – for example *C/A* means border of capturing and analyzing.

Business processes can be described at different levels of detail depending on the abstraction put into analyzing the organization. Both the purpose and level of abstraction relates to model characteristics. For example in case we want to present the process, we should choose a notation that is easy to understand, while when we want to use the created process model as an input to software engineering project, we would rather focus on specifying all necessary details related to development. The table 2.3 summarizes the purposes of Business Process Modeling, based on table 2.1, and for each of the main three purposes displays the required properties of the process model.

Purpose of process modeling [Aguilar-Savén]	**Usage of process modeling [Aguilar-Savén]**	**Usage of process models [Krogstie]**	**Purpose of process models [Phalp]**	**Application and benefits of BPmo [Hommes]**
Capturing	SW development	Model deployment and activation Input into traditional development project	Enactment support models to Information Technology Descriptive and analytical models for decision support to process development and design (C/A)	Requirements engineering
Analyzing	Decision making about process	Computer asisted analysis Quality assurance (A/P)	Enactable or analytical models for decision support during process execution and control (A/C)	Business Process Redesign Total Quality Management Simulation
Presenting	Documenting the process	Human sense-making Communication between people in organization	Descriptive models for learning	ISO certification Activity Based Costing

Table 2.2: Overview of Business Process Modeling and Process Models purposes and application

Business Process Modeling Purpose	**Required model properties**
Capturing	Models should provide legible and understandable view of the business process.
Analyzing	Models should present both dynamic and functional aspects of the process.
Presenting	Models should be easy to understand, typically diagrammatic notation is suitable.

Table 2.3: Properties of Business Process Model

2.4 Perspectives and techniques of Business Process Modeling

Organizational processes are usually very complex, and to deal with the complexity of an overall conceptual model, it is common to break down the model into a number of aspect models. General distinction of the aspects is ***static*** and ***dynamic***. The three classical perspectives are *data, processes* and *behavior*. The data perspective focuses on static aspects, processes and behavior on the dynamic aspect [48]. Generally, *perspective is a point of view that is considered when creating the process model*.

According to Webster's online dictionary, a *technique is the manner in which technical details are treated* [67]. In conceptual modeling, technique is considered to be a body of technical knowledge that guides modelers through the construction of a conceptual model of reality [48].

The techniques and perspectives are linked together in a way, that one technique models the processes from one perspective. Therefore most authors who define the list of perspectives include the techniques that belong to each perspective.

When modeling processes, we mainly focus on capturing the process dynamics. According to Bider [18], process dynamics can be modeled in 4 ways:

1. **Input/output flow:** I/O flow focuses on passive participants that are being produced, consumed or changed by activities. Most common technique in this perspective is IDEF0.

2. **Workflow:** Wf focuses on the order of activities in time. Among the typical workflow diagrams belong: IDEF3, Action Diagram (AD) of UML, developed by Eriksson & Penker, Petri Nets (they combine Wf and I/O flow, but Wf is dominant).

3. **Agent-related view:** This view focuses on the order in which agents get and perform their part of work. The typical notation use is RAD (Role Activity Diagram) and collaboration diagrams in UML.

4. **State flow:** In state flow each activity produces changes in the part of the real world. The flow is described in state-transition diagrams.

These 4 ways of process modeling however only cover the dynamic aspects. To get back to both aspects, the three classical perspectives, also mentioned by Hommes [48], commonly known as ***structural, functional*** and ***behavioral***, are by Krogstie [56] extended into 8 types of modeling approaches. He takes into account also aspects like goal, actor or communication, which leads him into following perspectives: **behavioral, functional, structural, goal-oriented, object-oriented, language action, organizational** and **topological**.

Behavioral perspective
Captures states of the modeled entity (systems/product/etc) and transformations between the states. *Examples: state transition diagram in UML, Petri-nets and CPNs, System dynamics.*

Functional perspective
It is the most popular one, because of its user-orientation. Processes are often divided into activities, which may further be divided into subactivities. Each activity takes inputs and transforms it into output. *Examples: IDEF3, Data-Flow-Diagram, Use Cases diagram.*

A special category is **Combined functional and behavioral perspective**, further referred to as **Functional & Behavioral**. *It includes: ARIS EPC, UML AD, BPMN.*

Structural perspective
It is handled by languages for data modeling, but also includes approaches from semantic networks and the semantic web. It focuses on static aspects, whereas process modeling on dynamic. *Examples: ER-modeling.*

Goal and Rule perspective
It defines boundaries within which the process operates, so instead of telling people what to do, the systems warns about rule violations and enforces constraints.

Object-Oriented perspective
Object-Oriented perspective follows the typical object orientation like encapsulation, polymorphism, subtyping and inheritance. UML is widely applied, because it is standard for the OOA&D, but the disadvantage is that UML is designed for software developers, not for end users. Challenge thus remains in mapping O-O UML constructs to user- and process- oriented concepts. *Examples: UML.*

Communication perspective
Communication, also often termed language action, is a perspective informed by speech act theory and Hamermas' theory of communicative action. It is basis for modeling of workflows as a coordination among people. Some approaches **combine aspects of functional and communicative** perspective, like *DEMO.*

Actors and Role perspective
Role-centric process modeling languages have also been applied for workflow analysis and implementation. *Examples: Role Interaction Nets, Role Activity Diagrams.* It primarily targets analysis of administrative procedures, where formal roles are important. The use of swimlanes in the BPMN has this effect.

Topological perspective
The concept of place can be related to a process, given that a place focuses on the typical behavior in a certain setting rather than where it is physically.

Similarly as with the purposes and usage of Business Process Modeling, different authors also presents different, more or less detailed classification of perspectives on process modeling. The three described approaches are summarized in table 2.4.

Perspectives to business process modeling			
Captured aspects	**Basic perspective**	**Krogstie**	**Bider**
dynamic	behavioral	behavioral	state flow
dynamic	functional	functional	I/O flow
static	structural	structural	
dynamic		Behavioral & functional (combination)	workflow
dynamic		rule/goal	
both		object oriented	
dynamic		communicational	
dynamic		actor-role	agent-related view
static		topological	

Table 2.4: Perspectives to Business Process Modeling

Krogstie [56] also summarizes which of the 8 identified perspectives have main application or some application in the areas of usage of Business Process Modeling, that were presented in table 2.2. The applicability of perspectives for particular usage of business process model is presented in table 2.4. Because Krogstie's list of perspectives to process modeling is the most detailed one, it will be the one used further in this thesis. The combination of Functional & Behavioral perspective is considered a separate category, making the total number of perspectives nine.

To get back to Business Process Modeling techniques, according to Recker [83], existing BPMo techniques falls into two categories. Firstly

Usage	Perspectives	
	Main applicability	**Some applicability**
Human sense-making - description of current state (AS-IS modeling)	Functional, Behavioral&Functional, Actor-role	Structural, Topological
Communication between people in organization	Functional, Behavioral&Functional, Actor-role	Structural, Topological
Computer assisted analysis - gaining knowledge about organization through simulation and comparison of AS-IS state and TO-BE state	Behavioral, Behavioral&Functional	Rule/Goal, Object-Oriented, Actor-Role
Quality Assurance - ensuring that organization acts according to a certified process	Functional	Behavioral&Functional, Rule/Goal, Actor-Role
Model deployment and activation (models can be activated through people or automatically using workflow systems)	Functional, Behavioral&Functional	Behavioral&Functional, Actor-Role, Topological, Rule-Goal, Communicational, Functional, Topological
Input into traditional development project	Functional	Behavioral, Structural, Rule/Goal, Object-Oriented, Actor-Role, Topological

Table 2.5: Applicability of BPMo perspectives for usage of BPMo

the intuitive graphical modeling techniques such as the Event-driven Process Chain (EPC), which are concerned with capturing and understanding processes for project scoping tasks and for discussing business requirements and process improvement initiatives. Secondly the Petri nets techniques, which are founded on mathematical, rigorous paradigms and are normally used for process analysis, execution, and simulation.

More detailed overview of the BPMo techniques provides Hommes [48], who identifies seven process modeling techniques (*Structured techniques, Flow Chart techniques, CPN based techniques, IDEF based techniques, Object Oriented techniques, EPC oriented techniques, Speech Act oriented techniques*) and Aguilar-Savén [8], who identifies 9 process modeling techniques (*Flow chart technique, Data flow diagrams – Yourdon's technique, Role Activity Diagrams (RAD), Role Interaction Diagrams (RID), Gantt Charts, IDEF, Colored Petri-net CPN, Object oriented methods, Workflow technique*). Comparison on both classifications of process modeling techniques is in a table 2.6.

As already mentioned, modeling techniques and perspectives to BPMo are closely related together, in a way that a technique focuses on modeling the process from one perspective. The table 2.7 matches all of the above identified techniques into Krogstie's [56] nine process modeling perspectives.

Business Process Modeling techniques according to:	
Hommes	**Aguilar-Saven**
Flow Chart techniques CPN based techniques IDEF based techniques Object Oriented techniques	
Structured techniques EPC oriented techniques Speech Act oriented techniques	Data flow diagrams – Yourdon's technique Role Activity Diagrams (RAD) Role Interaction Diagrams (RID) Workflow technique

Table 2.6: Overview of business process modeling techniques

Perspective	Techniques
Behavioral	CPN based techniques
Functional	IDEF based techniques, Data Flow Diagrams
Structural	Structured techniques
Behavioral&functional	Flow Charting, EPC, Workflow techniques
Rule/Goal	
Object oriented	Object Oriented techniques
Communicational	Speech Act oritented techniques
Actor-role	Role Activity Diagrams, Role Interaction Diagrams
Topological	

Table 2.7: Techniques and Perspectives of BPMo

2.5 Business Process Modeling method and methodology

Method should not be mistaken with a technique. *Method concerns the ordered way of working, it consists of interrelated tasks, which have to be carried out to get a desired result [48].*

Methodology is a body of methods, rules and postulates. It defines a particular procedure or a set of procedures [68].

Choosing a process modeling method

Business Process Modeling has a decade long tradition and a variety of products are available, based on different process languages. Selection is an important step. Besides organizational, economical, and overall IT infrastructure aspects, the expressive power of the process language as well as the interfaces to related software systems are important criteria [4]. Phalp [81] sees the **notation** and the **method** as two important considerations. However in practice, often rather than deciding firstly on technique and then on method, is the decision done the other way round.

According to Bider [18] the main facts that should be considered when choosing an approach to business process modeling are: **1) Properties of modeling objects; i.e. business processes, 2) Characteristics of the modeling environment;** and **3) Intended use of the model**. For example if an organization is functionally structured and processes are not identified, I/O technique or agent-related technique would be suitable, while for organization with defined processes, workflow view or state view should be applied [18].

Often some methods are closely connected to a tool. Kettinger et al. [52] surveyed 25 methodologies, 72 techniques and 102 tools. It is not a purpose of this thesis to go into details of those, however, since a brief overview of main BPMo techniques was presented, it is appropriate to finish this chapter by describing the relationship between methods, techniques, tools etc.

Not surprisingly, each modeling technique is suitable for different purposes of process modeling, meaning that the constructed process models have various applications and bring different advantages. The steps in choosing the process modeling method can be summarized as:

1. Identify the expected benefits
2. Based on the expected benefits, determine the purpose and intended use of the process model
3. Choose an appropriate perspective and technique
4. Choose a methodology or s method and notation
5. Choose a tool

Expected benefits and purpose (intended use) of the model go together. Firstly we should know what benefits we are hoping to gain. Base on that, by answering a question *"In what way the model will help us to achieve the benefits?"* we get an intended use of the model. These are the two fundamental and crucial steps. For example modeling processes prior to implementation of process-oriented information system would look differently than modeling processes for the purpose of documenting them.

Similarly, choosing a technique, methodology or method and notation go together. For example knowing that we want to model communication between actors within an organization, combination of functional and behavioral perspective would be most suitable.

We can choose between existing methodologies or methods and notations that support this technique. As already defined, methodology is a set of methods or rules, and notation and method are two important considerations. If there is a methodology, the choice is easy, as it would cover both method(s) and notation(s). For example when modeling processes for the purpose of documenting them, or communicating their flow to stakeholders, the choice of easy-to-understand notation is vital, while in case of modeling processes for the purpose of IS development there are other aspects then notation that matter more. As a last step comes the selection of appropriate modeling tool.

The relationship between modeling technique, perspective, method, notation and methodology can be summarized as:

- Each technique models processes from one perspective
- Tool may support multiple techniques, notations, methods or a methodology
- In case of more aspect models, each may have different notation
- Methodology may consist of more methods

2.6 Why BORM, BPMN and DEMO were chosen for comparison

The rest of this thesis focuses on describing and comparing the DEMO and BORM methodologies and the BPMN. Because the amount of methods, methodologies and technique for BPMo is very large, it would be impossible to compare all in the scope of this thesis. Therefore, based on discussion with the supervisor of this thesis, it was decided to limit the focus on the mentioned three. The main reason behind this choice is that they are very different.

The DEMO and BORM are methodologies, were each was developed to serve a different purpose. DEMO aims at modeling the construction and operation of an organization, while BORM focuses on modeling business processes, prior to software systems implementation. They both were developed in an academic environment, and implemented in organizations, both have a theoretical background and a potential to become more popular and spread out among practitioners.

The BPMN must have been included in the selection, because it is currently the most spread out and used notation for business process model. It is not a methodology, but a standard. Yet, it can be compared to the two methodologies, based on what each allows to capture, their application and benefits.

The difference is not only in the purpose of each, but also in the perspective, from which each methodology captures processes. Comparing three rather different methodologies is more interesting and allows to point out more benefits, because unified, they covered more aspects of the organizational and process modeling.

2.7 Summary

This chapter provided an introduction to Business Process Modeling and based on a literature search discussed purposes of process modeling, usage of the process models, perspectives on process modeling, process modeling techniques and organizational benefits that BPMo leads to. Many sources however mix purpose, application and benefits. It is true, that these aspects are interconnected with each other, yet the purpose of process modeling should not be mixed up with the usage. Table 2.8 summarizes the identified application of process models, created based on unification of multiple sources, supplemented by the purpose, model properties and applicable perspectives.

The identified application of business process models and process modeling may be mapped on the categories of process modeling benefits, summarized in table 2.1 and figure 2.2. Some of the application may belong to multiple levels – for example reporting may be done on the operational level, as well as on managerial level and process validation may be conducted at any of the lower levels - from IT infrastructure to organizational. This classification of the application of process modeling and categories of organizational benefits is displayed in figure 2.4.

Purpose of process modeling	Application of constructed process model	Model properties	Primary applicable perspectives	Perspectives with some applicability
Capturing	Process oriented Information system development	legibility, understandability, unambiguity	Functional, Behavioral & Functional	Behavioral &Functional, Actor-Role, Topological, Rule-Goal, Communicational, Functional, Topological, Object-Oriented
	Input into classical software development project			
	Requirements engineering			
capturing/analyzing	Process verification			
Analyzing	Process analysis - decision making about the process	presence of both dynamic and functional aspects	Behavioral, Behavioral & Functional, Functional	Rule/Goal, Object-Oriented, Actor-Role
	Process redesign / improvement / Change management			
	Process simulation			
analyzing/presenting	Knowledge management (reporting, knowledge sharing)			
	Alignment with organizational goals and strategic perspectives			
Presenting	Process documentation, understanding and learning about processes	unserstandability also for process owners - diagramatic notation	Functional, Behavioral & Functional, Actor-role	Structural, Topological
	Understanding the communication flow between entities in organization			
	Process validation			

Table 2.8: Overview of Business Process Modeling purposes and application

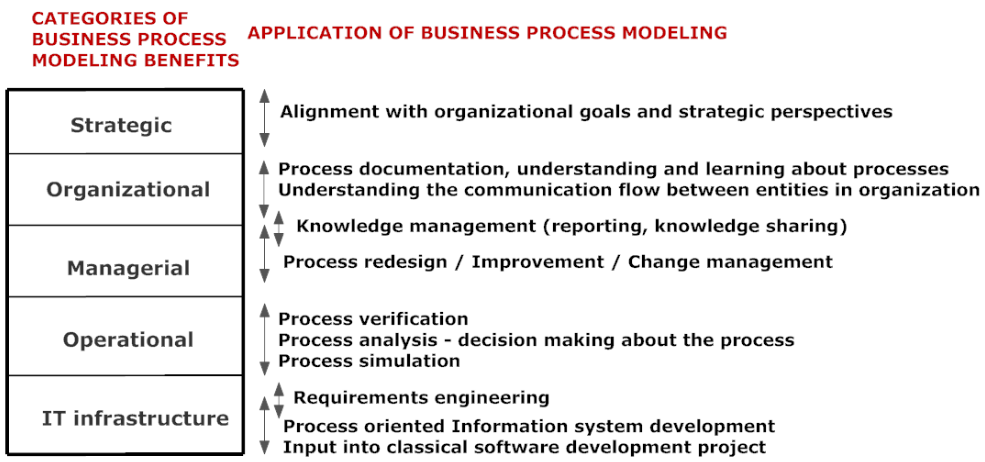


Figure 2.4: Application of Business Process Modeling in relation to benefits' category

Chapter 3

Business Process Simulation

3.1 Introduction

Simulation is the imitation of the operation of a real-world process or system over time [12]. It is a tool to evaluate the performance of a system, existing or proposed, under different configurations of interest and over long periods of real time [63].

Business Process Modeling should to be complemented with simulation for a thorough analysis and study of business processes, as only modeling may not reveal sufficient information about the processes [14]. Therefore **the aim of this chapter is to describe briefly simulation techniques that can be used for simulating business processes, steps in building a simulation model and advantages of business process simulation.**

To stay clear on the terms, ***simulation*** concerns simulation of any system, and ***business process simulation*** *focuses on simulating business processes.* The focus in this chapter and thesis is on Business Process Simulation, but prior to that, a simulation generally is briefly described.

3.1.1 Simulation

Number of organizations using simulation is rapidly increasing [13]. *Simulation is used to describe and analyze the behavior of a system, ask what-if questions about the real system, and aid in the design of real systems.* Both existing and conceptual systems can be modeled with simulation [12].

Simulation brings numerous advantages. Banks et al. [13] points out **13 areas where simulation can be used**. Simulation lets to test every aspect of a proposed change, it allows to investigate why a certain phenomena occur in a real system, explore new possibilities or diagnose problems. Because simulation models may become complex, and thus have a higher fidelity, they may also be used for identifying constraints, like production bottlenecks and headaches, visualizing the plan, preparing for planned changes by answering various what-if questions and specifying requirements for a system design [13].

The main obstacles lie in building the simulation model in a right way and interpreting the simulation results accurately. Furthermore, simulation may be very time consuming, thus expensive [13].

3.1.2 Simulation model

A model is defined as a representation of a system for the purpose of studying that system [13].

A model is description as well as abstraction of a system [12].

Models can be divided into *physical* and *mathematical*, which can further be classified as *static or dynamic, deterministic or stochastic* and *discrete or continuous* [12] [95], as visible in figure 3.1. A **simulation model** is a type of a mathematical model [13], [58].

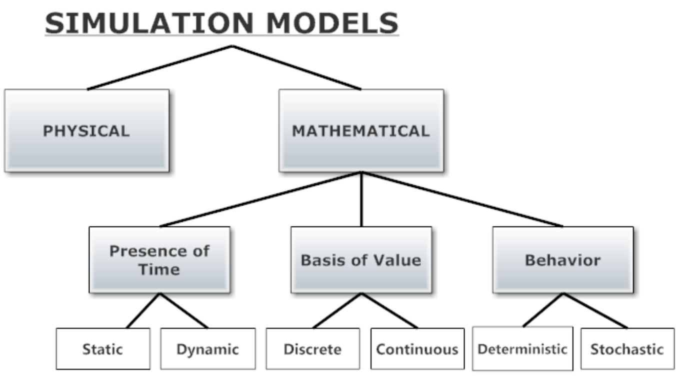


Figure 3.1: Types of simulation models

Most authors distinguish between two types of models, however the terminology may sometimes be ambiguous. Banks [12] uses terms **conceptual model** and **operational model**. A conceptual model is a representation of an actual system, which is then coded into an operational model. Law

[57] calls the models, which are defined just like by Banks [12], a **conceptual model** and a **programmed model**. Some authors use only term **simulation model** with no further explanation or definition.

For the purpose of this thesis is adopted a definition presented by Sargent [87], who distinguishes between a **conceptual model**, which is the *representation of the system that is developed through analysis and modeling,* and a **computerized model**, which is the *conceptual model implemented on a computer.* He defines a **simulation model** as a *conceptual model running on a computer system that allows experiments to be conducted on the model.*

3.1.3 Simulating business processes

The Business Process Simulation area has been used for analysis of business processes since the 1970s [88] and over the time has attracted a big amount of researches, like Law and Kelton [58], Gladwin and Tumay [40], Banks [12], Hlupic and Robinson [47], Desel and Erwin [31], Rozinat et al. [84] and others, who approach Business Process Simulation from diverse perspectives and point out various advantages and applications.

Because business processes are complex and dynamic, all Tumay [96], Paul et al. [79] and Aguilar et al. [7] agree that simulation appears to be a suitable method for Business Process Re-engineering. According to Desel and Erwin [31] the objective of simulation is to conduct a performance analysis, with respect to key indicators, which usually include waiting time, activity time and cost, and would be an important input into a business process (re)design. Also Tumay [96] and Hlupic and Robinson [47] consider performance analysis with focus on identifying bottlenecks and analyzing throughput times as a goal of simulation. Rozinat et al. [84] emphasizes the importance of simulation in operational decision making and prediction of complex dynamic behavior.

To sum up, simulation plays an important role in business process design as well as redesign, because:

1. It allows comparison of various design options

2. Based on a performance analysis, business processes may be analyzed and optimized (improved)

3. Experimenting with simulation model is less expensive then experimenting with a real processes

3.2 Simulation techniques

Simulation can be classified into ***Discrete Event Simulation***, ***Continuous Event Simulation*** and ***Hybrid Simulation***, as visible in figure 3.2 [45]. In a continuous simulation, states occur continuously across time. In a Discrete Event Simulation, state changes only occur at specific time intervals. A hybrid simulation comprises both continuous and discrete-event simulations [95].

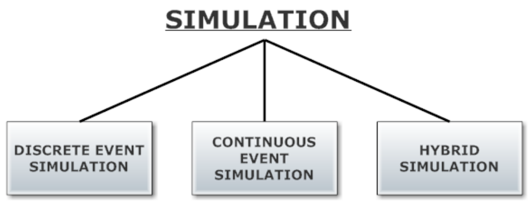


Figure 3.2: Simulation taxonomy [45]

The two mostly used techniques for business processes or organizational simulation is **Discrete Event Simulation** and **Agent Based Simulation**. Agent Based Simulation or modeling was not mentioned in the classification in figure 3.2, because Agent Based Model may be Discrete eEvent Model or hybrid of discrete and continuous, depending on its state variables [27].

3.2.1 Agent Based Simulation (ABS)

In the Agent Based Modeling (ABM), a system is described from the perspective of its constituent units and led as a collection of autonomous decision-making entities called agents. Each agent individually assesses its situation and makes decisions on the basis of a set of rules. The core of the ABM are repetitive competitive interactions between agents [20].

The Agent Based Simulation is applied for simulating flows, like evacuation or traffic flow, markets and diffusion – understanding a market place, and organization, like organizational simulation, operational risk and organizational design [20].

The Agent Based Modeling and Simulation is the right modelling technique mainly if the problem nature comprises of agents, the decisions and behaviours can be well defined and the agents have behaviour that reflects how individuals actually behave, including possibilities to adapt the behaviour [60].

3.2.2 Discrete Event Simulation (DES)

Discrete Event Simulation investigates how a system evolves over time. The state variables change instantaneously as separate points in time. At these points, some event occurs, that changes the state of a system [58]. The events occur as a consequence of activities, times or delays [12]. The goal of Discrete Event Simulation is to portray the activities in which the entities engage and thereby learn something about the system's dynamic behavior.

Entities, that flow through the modeled system, may compete over limited number of resources, possibly joining queues while waiting for a currently unavailable resource. Activity and delay times may hold entities for a specified duration of time. The system state is updated at each event, along with capturing and freeing of resources that may also occur at that time [12].

Discrete Event Simulation is the most powerful and realistic tool for analyzing the performance of business processes. Discrete Event Simulation is used for simulating project based processes, production based processes, distribution based processes and customer service based processes [96].

3.2.3 ABS vs DES

The Agent Based Simulation is different from classical Discrete Event Simulation due to the nature of agents, which are proactive, autonomous and intelligent [27]. The Agent Based Modeling is considered a better way to simulate the real-time interaction of people with their environment. Movement of entities in the DES typically requires predefined paths with decision points that dictate entity movement. Modeling human behavior with the DES is unrealistic in situations where paths are not predetermined [35].

Guizzardi and Wagner [41] conclude, that a business system is a social system (an organization) having one or more actors that are involved in zero or more business processes at any time, and since actors are essential for business systems, it is natural to use Agent Based Simulation for business simulation. It is however important to distinguish between business or organizational simulation, and simulation of processes. When simulating the organization with a focus on people or other working units, the ABS would reveal better insight into the dynamics of the system. The DES is more suitable for modeling process flow, where the sequence of tasks is set based on rules and entities move through the system based on the pre-defined paths.

According to Banks [12] a transaction-flow world view often provides the basis for the Discrete Event Simulation, where the system consists of discrete units of traffic that compete with each other for the use of limited resources while moving ("flowing") from point to point in the system. Therefore, **the focus in this thesis remains on the Discrete Event Simulation**.

3.3 Building a Simulation Model

The main challenge of the simulation lies in carrying out the simulation study in a right way [15]. According to Banks [12], Law [57] and Barjis [14], the first step to successful simulation is having a conceptually well-designed model. Building a model is a complex process. The simulation study involves a sequence of steps that lead into construction of a simulation model. Among crucial steps belong the model validation and verification.

3.3.1 Steps in a simulation study

Banks et al. [13], Law and Kelton [58] and Law [57] all present similar steps in a simulation study, which according to them, include:

1. Problem formulation;
2. Data and information collection;
3. Conceptual model construction;
4. Conceptual model validation;
5. Construction of a computerized model;
6. Computerized model verification;
7. Production runs and outputs analysis; and
8. Documentation and Implementation of results.

The conceptual model is developed though an analysis and modeling phase, the computerized model is developed through a computer programming and implementation phase [87]. Validation and verification are two very important steps, described in a greater detail bellow. Unless the conceptual model is valid, or computerized model verified, instead of proceeding to next step, the deficiencies must be corrected. All the steps are visible in figure 3.3.

3.3.2 Model validation, verification and testing

The model should be build with respect to a specific purpose and its validity determined with respect to that purpose [87].

Model validation deals with building the right model [10]. It includes determination whether the conceptual model is an accurate representation of the real system [12] [57] . Among aspects that help to build a valid model belongs formulating the problem precisely, interviewing multiple process users to get the accurate definition of the process and interacting with the users on a regular basis [57]. Furthermore, very useful is a walk-though the process, which shows the short-term dynamic behavior of a system, is useful for communicating the essence of a model to the decision-makers and other people who do not understand or care about the technical details of the model [57].

Model verification deals with building the model right [10]. It concerns the computerized model and whether it is working properly [12] [57]. It ensures that the computer programming and implementation of the conceptual model are correct. The simulation model can be built in various ways - using high level programming language or simulation language, and for each, the verification differs [87].

Model testing is ascertaining whether inaccuracies or errors exist in the model. In the model testing, the model is subjected to test data or test cases to determine if it functions properly [10]. There are two ways to test the simulation software – *static testing* and *dynamic testing*. In static testing, the computer program is analyzed by walk-throughs. In dynamic testing, the computer program is executed under different conditions and the values obtained are used to determine the model correctness [87].

3.3.3 Information needed to build a simulation model

An important pre-requisite of building a simulation model is knowing what information we actually need to have about the business process and the organization. This very often depends on the purpose of the simulation study or on the simulation tool, and that is why it is often not included in the description of steps in the simulation study. When simulating business processes, the purpose of the simulation study remains similar. Knowing the list of the elements and information needed to build a simulation model would help in evaluating or choosing a business process modeling technique - if we know the model will be further used for simulation, a technique, that includes all necessary details should be chosen.

Tumay [96] identifies 4 modeling elements: **flow objects, resources, activities** and **routings**. Flow objects, sometimes also called entities or tokens, flow through the process and are processed by resources. They can have attributes like due date, quantity etc. Resources are agents that add value to flow objects and are always allocated to activities. They may also have attributes, like rate or shifts. Activities may have attributes like time, cost or capacity and are connected by routings to represent the flow of objects through the simulation model. Routings define various types of connections between activities, can be deterministic, probabilistic or conditional and are followed by the flow objects.

According to Banks [12], the system consists of **entities, resources, control elements** and **operations**. Entities represent units of traffic, they are objects that flow through the system and may have attributes. Resources are system elements that provide service and are often limited in number. Control elements include for example switches, counters and arithmetic or boolean expressions, and support various control-related aspects of a system's state. An operation is a step or action carried out by or on entity during its movement through a system. Ordered set of operations is a sequence of steps or actions taken by an entity while it moves from point to point in a system.

(Rozinat et al. 2009)		**(Aalst 2010)**	
Elements	**Description**	**Elements**	**Description**
Control-flow	Causal relations between activities.	Control-flow	Order of activities, including splits and joins.
Decision points and rules	Data dependencies, decision points and rules for choice points.	Data/rules	Decisions made within the process, role that the data play.
Roles and resources	Roles, resources and their relationship.	Resources/organization	Allocation of resources to activities, resource availability.
Performance measures	Execution times, waiting times, probabilities for taking alternative paths and case generation scheme.	Time and probability	Duration of activities, likelihood of following a particular path.

Table 3.1: Modeling elements

Tumay [96] and Banks [12] present modeling elements as summarized in table 3.1. A different approach is introduced by Rozinat et al. [84] and Aalst [2], who define steps in discovering a simulation model.

Rozinat et al. [84] summarizes 4 steps in discovering a simulation model: **Control-flow discovery** reveals structural representation of the process and causal relations between the activities; **Decision point analysis** aims to discover data dependencies that influence the routings of a case and also to identify decision points and rules for choice points; **Performance analysis** should enhance the model by execution times, waiting times, probabilities for taking alternative paths and case generation scheme, which determines the arrival process – number of new cases per a time unit; and **Role discovery** should add roles, resources and their relationship.

Aalst [2] presents 3 perspectives that are needed to create a simulation model: **control-flow, data/rules, resources/organization**. **Control-flow** is concerned with the ordering of activities and uses design artefacts such as sequences, splits, joins and loops. **Data/rules** perspective models decisions made within the process and the role that data plays in these decisions. It is important not to model the data in too much detail and select the right abstraction level. **Resource/organization** perspective is concerned with the allocation of activities to resources, availability and speed of resources and organizational boundaries. Time (duration of activities) and probability (likelihood of following a particular path) play also an important role in running the simulation model.

(Rozinat et al. 2009)		**(Aalst 2010)**	
Elements	**Description**	**Elements**	**Description**
Control-flow	Causal relations between activities.	Control-flow	Order of activities, including splits and joins.
Decision points and rules	Data dependencies, decision points and rules for choice points.	Data/rules	Decisions made within the process, role that the data play.
Roles and resources	Roles, resources and their relationship.	Resources/organization	Allocation of resources to activities, resource availability.
Performance measures	Execution times, waiting times, probabilities for taking alternative paths and case generation scheme.	Time and probability	Duration of activities, likelihood of following a particular path.

Table 3.2: Steps in discovering a simulation model

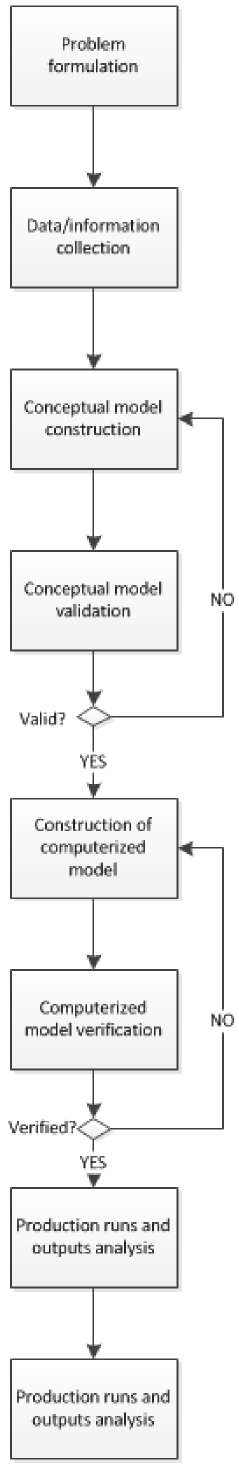


Figure 3.3: Steps in a simulation study

While the table 3.1 summarizes modeling elements, table 3.2 includes some additional information that would be needed for running the simulation model. All the elements and information needed for simulation and building a simulation model is summed up and presented in table 3.3.

Item *"Decision rules for decision points"* can be specified in two ways, as visible in table 3.2.

Element / Information	**Description**
Entities	Entities are objects that flow through the system; attributes of the entities are optional.
Activities	Activities in the process are sometimes also called steps, operations or tasks; attributes like time, cost, capacity etc. are optional.
Routings (Control-flow)	Routings define relations between activities – their order, splits and joins; they determine the flow of the objects.
Resources	Resources are elements that provide service and are allocated to activities; number of resources is optional.
Decision rules for decision points	Rules or probabilities for deciding on taking alternative paths.
Performance measures	Performance measures include execution times, waiting times, case generation scheme, resource availability.

Decision rules for decision points:	
Data (Attributes of entities must be specified)	Entities have specified attributes; entities flowing through the process contain data.
Rules for decision points	Decision rules for choice points; specifies the role that data play in those decisions.
OR	
Probability for taking alternative paths	Each place (decision point) has specified probability for taking alternative paths.

Table 3.3: Summary of all modeling elements

3.4 Usage of Business Process Simulation

It was mentioned earlier, that Business Process Simulation is used mainly for Business Process (Re)design and for Business Process Improvement. Business Process Simulation model may be used in two ways:

1. To visualize the process flow.

2. To conduct a performance analysis

3.4.1 Visualizing the process flow

Process flow visualization helps especially to validate the modeled process with process owners, users or analysts. The performance measures do not need to be included for this type of simulation. Yet, it adds a significant value to the process model, as it aims at confirming its validity. Already when performing a walk-through the process with its users or owners, duplicate or unnecessary activities should be identified, and subsequently eliminated.

3.4.2 Conducting a performance analysis

Performance analysis is used rather when comparing design options and improving, changing or optimizing processes. The simulation is done to find a way to increase service level, reduce total process cycle time, increase throughput, reduce waiting time, reduce activity cost and reduce inventory costs [96]. To analyze the performance of the process, the model has to include all performance measures, relevant to the measurement. Normally, those include times on activities, resources availability, delay, and routings for decision points.

3.5 Summary

This chapter provided an introduction to simulation generally and to the Business Process Simulation. The Discrete Event Simulation is the technique most commonly used and proved to be applicable for simulating workflows and business processes. The main goal of simulation is to gain insight into the modeled system, which is not revealed by modeling only. Simulation may be used either to visualize the process flow, or to conduct a performance analysis.

The most challenging in the simulation study is to build a valid and credible simulation model, for which a model validation and verification is used. Model validation deals with building the right model, while model verification deals with building the model right - accurately. As a prerequisite of a simulation study is considered knowing what information is needed in order to build a simulation model. This has been established based on literature search, is summarized in table 3.3 and will be further used in following three Chapters 5, 4, 6 and Chapter 7.

Chapter **4**

The BORM methodology

BORM (Business Object Relationship Modelling) is an object oriented and process based analysis and design methodology. Primarily, BORM was intended to provide seamless support for building object-oriented software systems based on pure object-oriented languages and environments. Subsequently, the method's potential in business process modeling has been realized [53]. The method has wider perspective on the whole problem domain, then just focusing on the information system itself, it facilitates the description of how real business systems evolve, change and behave [21].

The BORM methodology combines the **Object-Oriented approach**, where process models are composed of business objects, and **automata theory**. The methodology consists of **6 steps covering all stages of software development cycle**, but in each stage, only some aspects are modeled, which makes the models easy to understand also for stakeholders and process users [82].

4.1 Motivation

The Organizational Modeling is a vital part of the entire information development cycle. As explained by Brožek et al. [21], the major problem in software engineering with so-called requirement analysis arises in the initial stages of the entire information system development. Most common technique for requirements specification is Use Case modeling, as a start of UML documentation process. The classical UML, however, is not suitable for first stages of analysis, where business processes need to be recognized. The goal was to develop a methodology, that would smoothly go from business analysis and simulation to subsequent UML software development [21].

4.2 BORM methodology

The BORM methodology aims to cover the gap between the **Business Engineering** and **Software Engineering** [69]. It consists of **3 phases**, each of which has **2 steps**, making it **total of 6 steps**. First two are from the area of business engineering and the rest deals with software engineering. The intention when developing BORM was to solve the problem of mismatching between the actual business requirements and the software and how the requirements are understood by software engineers. The classical methods for business engineering do not include any connection to software development methods, and those do not verify and validate the inputs from business engineers. This is solved in BORM by negotiation, validation, verification and simulation [69]. Figure 4.1 displays the two areas and the gap between them.

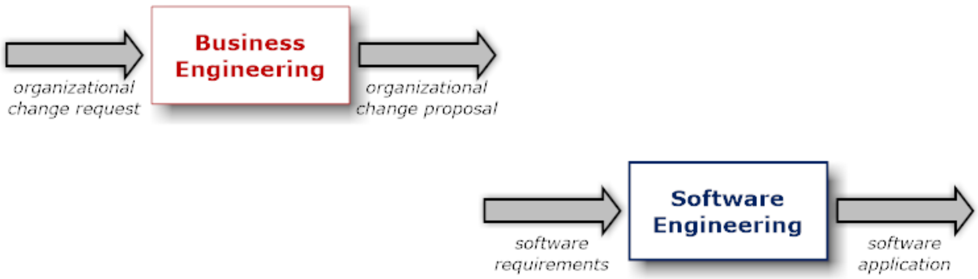


Figure 4.1: The gap between Business Engineering and Software Engineering

The BORM approach is based on two external stimuli that have influence on the Information system. They are **business changes** and **functionality of the information system**. [82]. The business changes lead into organizational change request, which represents an input for Business Engineering phase. Changes in functionality lead into Software Requirements, that represent an input into Software Engineering phase [69].

A BORM model consists of **objects** and **processes**, that are in a relation with the two external stimulus. The business model of an organization should be clear and accurate, and by a set of transformation, an IT model is created, which can be used by software developers.

BORM can be characterized by three aspects [71]:

1. It covers all stages of software development cycle, and pays attention to preliminary phases, so-called business analysis, that include

identifying objects and their validation.

2. Concepts and their notation change as the development process proceeds. For each phase of the life cycle, there is a different set of terms used. By this, only the relevant details for each phase are included. The steps rather than adding details to a model from one phase to another transform the model throughout the life cycle.

3. Most symbols used in BORM are the same as in UML, but in comparison with UML or other development methodologies, one BORM diagram can cover information that would normally be found in multiple diagrams. This allows to model in a consistent way some important details of a system's construction, making it easier for system analysts.

4.3 Modeling with BORM

This section explains the **BORM Life Cycle**, which covers the whole development process from business process modeling, through construction of conceptual and software models up to software implementation. Since BORM does not divide static and dynamic views of the model, it only includes three diagrams – the **Business Architecture diagram**, the **Object Relationship Diagram** and the **Class Diagram**. The description of the models and the method is based on [82], unless other source is specified.

4.3.1 Life Cycle

BORM is based, like other OOA&D methodologies, on a spiral model of the development life cycle [53]. One loop contains 6 stages – **strategic analysis, initial analysis, advanced analysis, initial design, advanced design, implementation** and **testing**. The first three stages are referred to as **expansion stages**, and end with finalizing of the detailed analysis conceptual model, which fully describes the solution of the problem from the requirements point of view. The other three stages are called the **consolidation stages** and during those the conceptual model is transformed, refined, reduced and finalized into a software design [53]. Software Development Life Cycle in BORM is presented in figure 4.2, summary of all six steps of the method and their position in the three stages is displayed in figure 4.3.

The 6 steps in BORM lifecycle are:

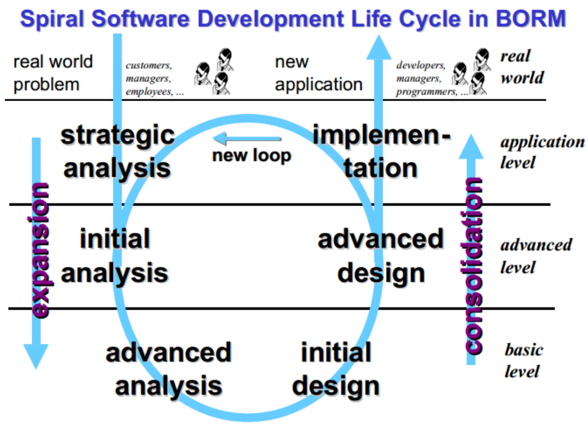


Figure 4.2: The BORM methodology lifecycle [54]

1. **Strategic analysis** – problem definition, scope, process identification
2. **Initial analysis** – process mapping, object attributes identification; goes from AS-IS situation to TO-BE situation
3. **Advanced analysis** – details of each object class, relations between objects (composition, inheritance and dependencies), scope of the modeled software system and user interface
4. **Initial design** – preparation for software implementation
5. **Advanced design** – transformation of model into implementation-specific model
6. **Implementation** – implementation and testing of the software

4.3.2 Elementary elements

Two core elements in the BORM methodology are **process** and **object**. Each object has three independent attributes called dimensions, namely *data, behavior and history* [53].

Object

Object is present in all stages of the life cycle, but in each stage has different characteristics. They can basically be divided into three types:

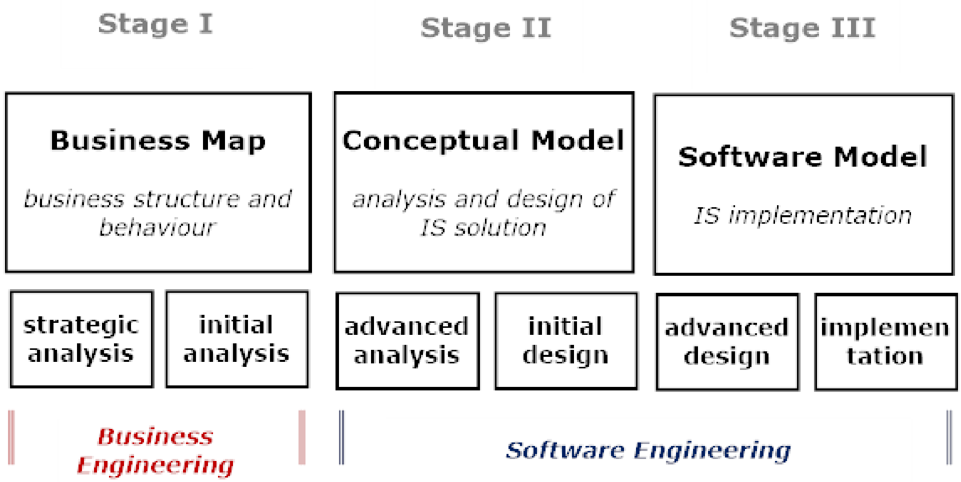


Figure 4.3: Stages in the BORM methodology

1. **Business Objects** – real world objects that can be found in the first stage of the life cycle, they have history and communicate with other objects.

2. **Conceptual objects** – objects that are used in the second stage of the life cycle, have typical characteristics of object oriented paradigm.

3. **Software objects** – objects that are used in the third stage and contain attributes and characteristics that are used in object oriented programming languages.

4.3.3 Object Behavioral Analysis (OBA method)

Method *OBA (Object Behavioral Analysis)* is used to get structural information that is needed for construction of the initial object model. Because it focuses on the information we need to know in order to construct the main diagram used in the first stage in BORM, the steps are briefly summarized.

1. **Process identificatio**n – getting the process description, participating objects and description of the result.

2. **Object definition** – creating so-called model cards, which include for each object its name, list of activities and objects it collaborates with.

3. **Object classification** – model cards are enriched by additional information and grouped by different criteria.

4. **Objects relations table** – summarizes relations between objects.

5. **Object life cycle model** – each object has a set of states and transitions it goes through, during its life cycle.

4.3.4 Object Relationship Diagram (ORD)

The *ORD (Object Relationship Diagram)* visually represents information about processes and objects identified by the OBA method. The elements presented in the diagram are: **Object** (Participant), **State** and **Activity**. They can be connected by **Association** (data oriented flow), **Communication**, **Transition** and **Conditional** links. Notation used in the ORD diagrams is in Appendix C.

The main element is a participant/object that takes part in the modeled process. In ORD is clearly displayed a sequence of steps performed by the participant. There are two types of steps – activities (modeled as ovals) and states (modeled as boxes), which always alternate. Participant can start its role in a state, in which case this state is the initial state of the process, or he can start in an activity, which is invoked externally by communication link from other participant. Similarly, the end state included in a participant role is one of the possible ending states of the process. Communication links in between the participants are also between activities.

The ORD is a combination of a *Petri net technique*, which allows to model states and transitions,and *Mealy automaton*, which captures communication between objects [21] [82]. This allows to model two aspects of the process:

1. Sequence of states and transitions that shows the **role of the object in the modeled process**.

2. Sequence of communication links between activities of objects in different states, which shows the **actual flow of the process**.

The interaction between the participants can be clearly seen also from the Object Relations Table. Both the table and the ORD are created based on information gained by the OBA method, as a part of the first stage in the BORM life cycle.

Relevance of the ORD: *The ORD shows states, activities, transitions and operations for all subjects (business objects) playing role in a business* *process, which makes it a powerful diagram. It conveys information which in the UML would require at least two diagrams, but despite the large amount of information, it is clearly understood by stakeholders [53]. The ORD is the main diagram in the Stage I and an initial diagram for the whole BORM life cycle. Since it can be simulated, verified and validated by process users and yet transformed into conceptual model, it helps to bridge the gap between Business Engineering and Software Engineering.*

4.3.5 Business Architecture diagram (BA diagram)

The BA diagram depicts the process architecture. It covers all the processes and the (business) units of the modeled organization. It clearly displays which process belongs to which unit as well as the links between the processes.

Relevance of the BA: *The BA provides the whole architecture of the processes of the modeled organization. It makes clearly visible which processes are in a relation and under which part of business (business unit) they belong.*

The other two stages do not concern process modeling, but rather software engineering, which is not a primary focus of this thesis, but to make the overview of the BORM method complete, the transformations into the other stages is briefly mentioned. The transformation is in greater detail described in [94].

4.3.6 From Business Engineering to Software Engineering

Stage I to Stage II

Transition from first to second stages involves transforming **Business Objects** to **Conceptual Objects**. Created diagram in this stage is modeled in UML and comprises simple conceptual object relation diagram.

Stage II to Stage III

Transition from Stage II to Stage III focuses on transforming **Conceptual Objects** to **Software Objects**. The software diagram is obtained by simple transformation from type hierarchy into an inheritance hierarchy and aims to fit the conceptual objects into the concrete software environment. Final diagram constructed in this stage is the Software Component diagram [53].

4.3.7 Steps in creating a BORM model

Based on the description of BORM, all steps in BORM project life cycle can be summarized as follows:

1. Getting information about the system using the the OBA method *(Stage I)*

2. Construction of the BA diagram *(Stage I)*

3. Construction of the ORD *(Stage I)*

4. Transforming the BOs to COs and the ORD into the conceptual object relation diagram *(Stage II)*

5. Transforming the COs to the SOs and the conceptual object relation diagram into the software diagram *(Stage III)*

6. Construction of the Software Component diagram *(Stage III)*

4.4 Application of BORM

The main application of the BORM methodology would be in information system development, based on process analysis of the organization, which was the initial motivation for developing the methodology. As stated by Brožek et al. [21] the BORM methodology has proved to be effective in the development of business systems.

The result of a first stage of the BORM project life cycle - the so-called *Business map*, which captures the business structure and behavior, can be further used, as summarized by Merunka [69], in multiple ways:

1. Requirements for software engineering can be derived from it, which is described in the other two phases of the BORM life cycle.

2. AS-IS and TO-BE process models can be used for business improvement.

3. Documented subjects and behavior can be used for organizational consulting.

4. Captured information can be used as an input for knowledge management.

4.5 Advantages of BORM

Merunka [70] summarizes following 4 advantages of the BORM Process Modeling:

1. **Participant History Diagram** – shows the progress of the participant through its relevant activities and states
2. **Process-Participant Interaction Model** – displays the histories in collaboration between the participants, the process is expressed by such a communications
3. **Self Correcting set of activities** – the BORM methodology enables to trace who is involved in which activity and their particular responsibility, which would be particularly helpful for Business Process Re-engineering
4. **A Unified Approach** – the BORM methodology provides consistent set of concepts with concise graphical representations

Not to keep on talking only about the first stage – the process modeling, there are some advantages of the whole BORM methodology.

Authors see the highest value of BORM in the ability to cover two different worlds: Business Engineering and Software Engineering [21]. They see the advantage over other functional modeling methods, that the BORM model presents the captured knowledge about the system in a more effective way than other business processes, data or functional modeling methods, while at the same time its graphical model is easy to understand for business users. In addition to that, clear rules specify how to progress through the system development process using this knowledge representation [53]. The BORM methodology has a wider perspective on the whole problem domain, then just focusing on the IS itself. Based on process analysis, it starts with identifying relations between the real world objects (participants in the process), as those will be later part of software objects of IS, which should ensure that the produced IS is aligned with the business needs [82].

The last advantage is the proved readeability and understandability of the ORD for stakeholders and business users [53]

4.6 Simulation

The ORD may be directly simulated. It has the syntax and semantics for simulation, because the diagram is a combination of a finite state automaton and a Petri net. The simulation may be done either in a tool designated for it, like the Craft.CASE [29], or the diagram may be easily created in any other Petri net simulator, like for the CPN Tools [28], or any other from numerous available tools [80].

The simulation of BORM models in the tool designated for it, like [29], is done rather for the purpose of visualizing the process flow. However, since the model can be straightforwardly implemented also in a Petri net, then by adding the performance measures, full performance analysis of the process may be conducted. All information needed for building a simulation model, summarized in Chapter 3 table 3.3, is covered in the BORM model, except of the performance measures, and joins for the parallel flow.

Chapter 5

The BPMN

The BPMN (Business Process Model and Notation) is a standard that defines a notation for business process models. It has been developed by the Business Process Management Initiative (BPMI) and is now further being maintained by Object Management Group (OMG). The main goal of this notation, as defined by the OMG, is to be "***readily understandable by all business users, from the business analysts that create the initial drafts of the processes, to the technical developers responsible for implementing the technology that will perform those processes, and finally, to the business people who will manage and monitor those processes***" [74] .

The BPMN is an expressive language, able to describe nuances in process behavior compactly in one diagram, the *Business Process Diagram (BPD)*, while at the same time the meaning is precise enough to describe the technical details that control process execution. Thus, BPMN aims on creating a standardized bridge for the gap between the business process design and process implementation [91].

The BPMN originated in 2002 and in that time stand for ***Business Process Modeling Notation***, meaning that the focus of the standard was on unifying the notation used in the BPD [91]. The most effort in creating BPMN 2.0, the currently used version of the standard, involved the M - the model. That means the formal semantics of the elements definitions and their inter-relationship. The notation, shapes and symbols changed very little from BPMN 1.2 to BPMN 2.0 [91].

The BPMN consists of one diagram – the Business Process Diagram (BPD), which is based on flowcharting technique. The diagram is both a visualization and a data entry for the underlying XML semantic model. A process in BPMN is defined as ***a sequence flow, which can consist***

of events, activities and gateways. Each sequence flow has a starting and an ending point [91].

5.1 Motivation

According to Owen [78], there are two goals with which the BPMN was created. The first goal was to **provide a notation that is understandable for all business users** - from business analysts to technical developers, because existing process diagramming standards, like UML, are considered to be too IT-centric [91]. The second, equally important goal, is to **ensure that XML languages designed for the execution of business processes can be visually expressed with a common notation**.

5.2 Modeling with BPMN

The OMG declares that the BPMN has no official methodology. As **M** stands for **Model** and **N** for **Notation**, the BPMN specifies two things – the modeling notation and a formal semantics of the elements' definitions and their inter-relationship. The BPMN specification makes no distinction between its elements that are part of the non-executable model, which are displayed in the BPD, and those that are required for executable implementation, which are not displayed in the BPD. Those include element definitions or associated rules [91].

The technical structuring of the BPMN is based on the concept of extensibility layers on top of a basic series of simple elements identified as Core Elements of the specification. From this core set of constructs, layering is used to describe additional elements of the specification. Those extent and add new constructs to the specification and rely on clear dependency paths for resolution [74]. The structure of the BPMN is visible in figure 5.1.

Understanding the BPMN therefore only involves understanding the notation used to express different aspects of the process. The fact, that the BPMN does not include any methodology that would define how the process models should be created, has both advantages and disadvantages. The analysts can decide the level of abstraction they will use, depending on the purpose. The drawback however, lies in the precision of the model, as each analyst would very likely model the process in a slightly different way. The goal, however, is to make all analysts model one process based on one process description in as similar way as possible, which forces organizations into specifying their own methodological instructions for process modeling.

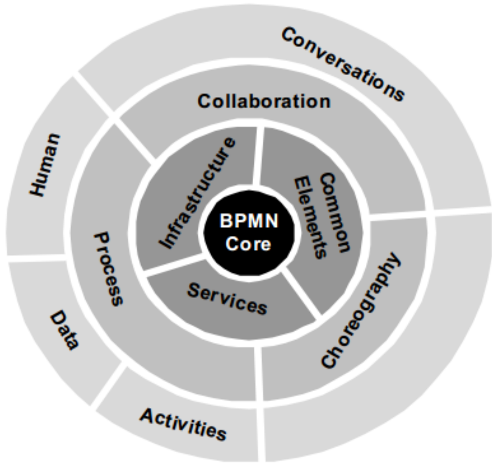


Figure 5.1: BPMN core and layer structure [74]

Silver [91] presents a methodology for creating *"good BPMN"* models, which is summarized later in this chapter, and is adopted for the case study, presented in chapter Chapter 8.

5.3 Elementary modeling elements

5.3.1 Fundamental concepts

The two most fundamental concepts in the BPMN are activity and process, which Silver [91] describes in a following way.

Activity

An activity is an action, a unit of work performed repeatedly in the course of business. It is the only element that has a performer. Each instance of the activity represents the same discrete action with a well defined start and end.

Process

A process is a sequence of activities leading from an initial state of the process instance to a defined end state. The process model is a map of all the possible paths (sequences of activities) from initiating event to any defined end state (success or exception).

5.3.2 BPMN Elements

The five basic categories of elements are [74]: **Flow Objects, Data, Connecting Objects, Swimlanes and Artifatcs.**

1. **Flow Objects:** main graphical objects that define behavior of a business process; can be further divided into: Events, Activities and Gateways.

2. **Data:** can be divided into: Data Objects, Data Inputs, Data Outputs and Data Stores.

3. **Connecting Objects:** define four ways of connecting the Flow Objects: Sequence Flows, Message Flows, Associations and Data Associations.

4. **Swimlanes and Pools:** objects can be grouped into Pools and Lanes.

5. **Artifacts:** are used to provide additional information about the process.

The notation of the modeling elements is in Appendix C. The most important in the process are the flow objects – activities, events and gateways, because they define the process flow. Activity was described above, Events and Gateways follow.

Events
Events define how the process responds to a signal that something happened, or how the process generates a signal that something happened. The BPMN defines **start events**, describing how the process is started, **end events**, defining possible termination / end states and **intermediate events**. Those allow to model situation when action is required immediately upon occurrence of a specific trigger signal. Timer Events depend on a time period or event, and Message Events on receiving/sending a message.

Gateways
Gateways define splitting and merging in the process. They can be parallel (when activities are executed in parallel), exclusive (choice between two options) and OR Split (choice between multiple options). From the advanced worth mentioning are Complex gateways, which allow to model more complex decision rules, and Event based gateways, where decision is done based on type of incoming event – normally an external message.

5.4 Business Process Diagram (BPD)

The BPD reveals only the order of activities, when they happen, and under what conditions. It describes what happens next when an activity completes. It does not describe how, where or why an activity happens [91]. The BPMN allows to model a sequence flow as well as communication within the process and between the process and external entities.

5.4.1 Sequence flow

A sequence flow consists of activities that can be either a single task or a sub process. A task is an entity of work that cannot be broken down in other entities of work. A sub process can be broken down in multiple entities of work, which are arranged according to its own sequence flow. Even though called sub-process it has all parameters just like a process, including starting and ending point.

In the BPMN a process is contained within a pool, which is a graphical representation of a participant, or can present a logical unit of a modeled organization. A pool can be subdivided into lanes. Although their use is not explicitly defined in the BPMN they are often used for internal roles. In one pool should be placed always only one process, with starting and ending point.

A sequence flow can have multiple branches which can be parallel, exclusive or a combination of these, which is determined by the used gateway. Besides those, the routing may depend on the events.

5.4.2 Communication flow

Communication between pools is made explicit and communication between lanes in a pool is not represented. In the BPMN there are three ways to represent communication between pools: **choreographies**, **conversations** and **collaborations**. Communication can be **within an organization** (internal communication), and communication **between different organizations** (external communication). This distinction can be done by creating multiple pools.

5.4.3 Types of sub-model within the BPD

The BPD allows to model three basic types of sub-models [74]:

1. **Processes** (Orchestration), including:

   a) **Private (internal) Business Processes** - Processes that are internal to a specific organization. These Processes have been generally called workflow or BPM Processes.
      - **Non-executable** - modeled for the purpose of documenting process behavior at a modeler-defined level of detail.
      - **Executable** - modeled for the purpose of being executed.

   b) **Public Processes** - a public Process represents the interactions between a private Business Process and another Process or Participant. Only those Activities that are used to communicate to the other Participant(s) are included in the public Process.

2. **Choreographies** - definition of the expected behavior, between interacting Participants. While a normal Process exists within a Pool, a Choreography exists between Pools (Participants).

3. **Collaborations**, which can include Processes and/or Choreographies - a collaboration depicts the interactions between two or more business entities. The Message exchange between the Participants is shown by a Message Flow that connects two Pools.

   a) **A view of Conversations** - informal description of a collaboration diagram; conversation is the logical relation of Message exchanges.

Relevance of the BPD: *Besides the mentioned types of sub-models within BPD, its main advantage is that it is easy to use and understand for business users. Furthermore, its expressiveness allows to model complex business processes that can be at the same time naturally mapped to business execution languages [78].*

5.5 BPMN Method and Style

Silver [91] in his book makes a distinction between *"bad BPMN"*, where model is invalid, incomplete or ambiguous, and *"good BPMN"*, which should be *correct, clear, complete* and *consistent*. The BPMN specification demands only correctness, which is for *"good BPMN"* insufficient. *"Good BPMN"* requires adopting conventions that go beyond the requirements of the specification, that he calls the **Method and Style**. He describes a methodology that would ensure creating a *"good BPMN"* and suggests that each organization normally has its own methodology for process modeling using the BPMN and his can be taken as a starting point and adapted to fit the needs of each organization. The fact, that the BPMN does not present a modeling methodology allows each organization to adopt their own methodology, based on the purpose of process modeling - whether they need to capture AS-IS process models, or TO-BE, or details for implementation. Silver's [91] methodology (Method and Style) is summarized below.

5.5.1 The Method

The Method is based on hierarchical modeling style that reveals important basic facts about the process in the top-level diagram and details in child-level diagrams. The method aims on modeling in compliance with the principles of *"good BPMN"*, which are [91]:

- **Completeness:** All essential elements should be captured in the diagram, including how the process starts and all possible states and ends.
- **Clarity:** Details of the process flow (routing, conditions) should be unambiguous from the diagram alone.
- **Shareability between business and IT:** The BPD should be understandable for both business and IT.
- **Structural consistency:** Given the same description, modelers should create more or less the same process model.

The Method consists of following 6 steps [91]:

1. Agree on process scope, when it starts and ends, what the instances represents, and possible end states.
2. Enumerate major activities in a high-level map, ten or fewer, each aligned with the process instance. Think about possible end states of each activity.
3. Create top-level BPMN diagram. Arrange high-level map activities as sub-processes in a BPMN process diagram, with one top-level end event per process end state. Use gateways to show conditional and concurrent paths.
4. Expand each top-level sub-process in a child-level diagram. If sub-process at parent level is followed by a gateway, match sub-process' end states to the gateway (or gate) labels.

5. Add business context by drawing message flows between the process and external requester, service providers, and other internal processes, drawn as black-box pools. Message flows connecting to collapsed sub-process at parent level should be replicated with same name in the child level diagram.

6. Repeat steps 4 and 5 with additional nested levels, if any.

5.5.2 BPMN Style

The basic principle of BPMN style is, that process logic should be unambiguous from the diagram alone. Some of the rules are the official rules, arising from BPMN standard, some are not, but should be, according to Silver [91], used to maximize shared understanding of the BPD. The list comprises 25 items listed below. Without knowing the rules, one would still be able to read the process diagram, if familiar with the notation, but definitely will not be able to create a *"good BPMN"* process diagram.

1. Use icons and labels to make the process logic clear from the printed diagram.

2. Make models hierarchical, fitting each process level on one page.

3. Use a black-box pool to represent the Customer or other external requester or service provider.

4. Begin customer-facing processes with a Message start event receiving a message flow from the Customer pool.

5. If you can, model internal organizational units as lanes within a single process pool, not as separate pools. Separate pools imply independent processes.

6. Label process pools with the name of a process label black-box pools with a participant role or business entity.

7. Indicate success and exception end states of a process or sub-process with separate end events, and label them to indicate the end state.

8. Label activities VERB-NOUN (i.e. Check credit, not Credit check or Credit OK).

9. Use start event trigger in top-level process to indicate how the process starts.

10. If a sub-process is followed by a gateway labeled as a question, the sub-process should have multiple end events, and one of them should match the gateway label.

11. Show message flow with all Message events.

12. Match message flows in parent- and child-level diagrams.

13. Label message flows directly with the name of the message.

14. Two end events in a process level should not have the same name.

15. Two activities in a process model should not have the same name.

16. A sub-process should have a single None start event.

17. A process pool in child-level diagram (if drawn) should be labeled with name of the top-level process, not the name of the sub-process.

18. In a hierarchical model, a child-level diagram may not contain any top-level processes.

19. Don't use XOR gateway to merge alternative paths, unless into another gateway. Just connect the sequence flows directly.

20. Don't use an AND gateway to join parallel paths into a None end state. A join is always implied at a None end state.

21. A sequence flow may not cross a pool (process) boundary.

22. A sequence flow may not cross a sub-process boundary.

23. A message flow may not connect nodes in the same pool.

24. A sequence flow may only connect to an activity, gateway, or event, and both ends must be properly connected.

25. A message flow may only connect to an activity, Message (or Multiple) event, or black-box pool, and both must be properly connected.

5.6 Application of BPMN

The BPMN is mainly used for creating standardized process models. According to the OMG [74] the goal and application of the BPMN is to enable portability of process definitions, not dependent on a specific vendor. The BPMN is constrained to support only the concepts of modeling that are applicable to business processes. Business process modeling is used to communicate a wide variety of information to a wide variety of audiences. The BPMN aims to cover three basic models of processes: **private** (executable and non-executable) and **public processes**, **choreographies** and **collaborations**. Within and between these three sub-models, many types of diagrams can be created, like [74]:

- High-level non-executable process activities (not functional breakdown)
- AS-IS business process
- TO-BE (new) business process
- A description of expected behavior between two or more business participants (a choreography)
- Detailed private / public business process (either executable or non-executable), optionally with interactions with one or more external entities
- Two or more interacting detailed executable processes (public or private)

Process documentation
First of the two main applications of the created BPD, is to document the process AS-IS. The diagram's value is that it conveys the process logic in a meaningful way [91]. The diagram can be created with a different level of a detail, depending on the specific needs. Normally, Business Processes Modeling starts with capturing high-level activities and then drilling down to lower levels of detail within separate diagrams [100].

Process Implementation (execution)
BPMN allows to model the processes also at the operational level, which can be used as a starting point for implementation (execution) of business processes. Not only because the process' operation is captured, but also because all the technical details necessary for execution are included. The processes are implemented using various available software tools.

5.7 Advantages of BPMN

According to multiple sources [37] [91] [74] the main advantage of the BPMN lies in its readability and usability for business process owners and business users, as no special knowledge is required to understand the graphical notations.

Furthermore, the BPD covers the business view that targets the business analysts who use the BPMN to create business process models and the technical view, which is used by technical developers who will need to add detailed technical specifications to make the models executable [75].

The BPD can be implemented, due to its mathematical foundations which make it possible to map the processes to business execution languages, which puts the BPD in an advantage over the UML. The BPD can be also mapped to UML diagrams for further systems design [78].

5.8 Position of BPMN in BPM

The activity flow logic, as defined by the BPMN, is only one component of the modeling needed to properly describe, analyze, transform and optimize a company's business processes. The sequencing of activities encompasses a lot, but a lot more information is needed to do BPM properly [91]. The BPMN does not capture high-level business context, like description of the organization's relationship with competitors or partners, policies, operational goals, performance metrics and KPIs, as well as process specific and technical details, like resource requirements or IT systems and data.

5.9 Simulation

The BPD captures well the process flow and is suitable for simulation. Wagner et al. [98] analyzes thoroughly the BPMN and its suitability for creating Discrete Event Simulation models. He concludes, that BPMN is suitable for simulation, because is very well able to represent the event flow dynamics, but he points out two minor shortcomings of BPMN with regard to simulation modeling – one considers special type of gateway, and another association between scheduled event and task.

For BPMN a vast number of software tools is available, and the possibilities of simulation very much depend on the selected tool. Generally, the visualization of process flow is possible and useful especially for communicating and validating the modeled processes. Performance analysis is also used, for the purpose of process optimization and comparing design options [78].

If one desires to use a technique like Petri net for simulating the process, the BPD may be translated into a Petri net. Since Petri net is proved to be suitable for modeling workflows [85] [5] and the BPD captures business processes and workflows, the translation of the BPD into a high-level Petri net model is not difficult. However, in most cases already existing simulation tools would be used, and therefore the simulation options are dependent on the tool. The details or comparison of the tools is out of the scope of this thesis.

All information needed for building a simulation model, summarized in Chapter 3 table 3.3, is covered in the BPMN. The resources are in the BPD optional, but as a best-practice are included in pools and swimlanes.

Chapter **6**

The DEMO methodology

DEMO (Design and Engineering Methodology for Organizations) – a methodology for (re)designing and (re)engineering organizations that has been laid down by Dietz [32], presents a systematic way of developing the ontology of an enterprise. It is based on the Ψ-theory (or PSI – Performance in Social Interaction) developed by Dietz [32], which has roots in Habermas' [42] and Bunge's [22] [23] studies. A complete so-called essential model of an organization consists of four aspect models: *Construction Model (CM), Process Model (PM), Action Model (AM) and State Model (SM).*

DEMO reveals the construction and operation of an organization and is characterized by three major features, as summarized by Shishkov and Dietz [90]:

1. A white box architecture of actors, production and coordination: social actors in enterprise can perform coordination acts and production acts.

2. The extraction of the essence of business processes from their realization: the organization is viewed at from three perspectives: essential or ontological, infological and datalogical.

3. The transaction pattern: transaction pattern defines a transaction as a sequence of coordination/production acts between two actors. It ensures that all coordination acts, even those performed tacitly, are detected.

6.1 Motivation

There are a lot of methodologies in the area of Business Process Modeling, so why another new methodology? The authors give following reasons for developing DEMO.

Modern enterprises are growing in a complexity as well as ICT in the enterprise, causing that the ICT applications do not meet business requirements. The business-IT alignment is a big topic, and there is not a perfect methodology, that would solve the existing issues.

When implementing changes in organizations, information systems science fall short, as well as organizational science does. The reason behind that is that the managerial approach (function oriented, black-box approach) requires the engineering approach (construction-oriented, white-box thinking) [86]. Enterprises are purposefully designed systems that can be re-designed and re-engineered. As summarized by Barjis [15], a modern enterprise is a complex composition of interrelated social and technical components. The communication and interaction between the actors in the process are important aspects, which are not covered properly by other modeling techniques. Dietz [32] sees the enterprise ontology to be best suited for understanding the operation and construction of an enterprise. **DEMO was developed to be a methodology for creating an ontological model of an enterprise**.

6.2 Enterprise Engineering and Enterprise Ontology

Enterprise Engineering is an emerging discipline. The mission of Enterprise Engineering is to combine (relevant parts from) the traditional organizational sciences and the information systems sciences, as you can see in figure 6.1, and to develop emerging theories and associated methodologies for analysis, design, engineering, and implementation of future enterprises [86]. Enterprise engineering includes **Enterprise Ontology** and **Enterprise Architecture**.

6.2.1 Enterprise Ontology

The ontological model, based on the **Ψ-theory** (described in detail in a following chapter) satisfies the C_4E quality requirements, namely it is: *Coherent*, *Comprehensive*, *Consistent*, *Concise* and *Essential* [32]. It covers basic, systematic and integral understanding of how enterprises work.

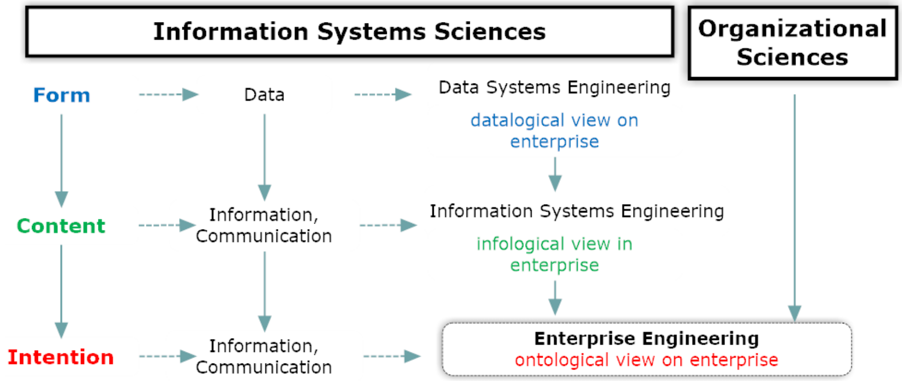


Figure 6.1: Position of Enterprise Engineering

- *Coherent*: the distinguished aspect models constitute a logical and truly integral whole
- *Comprehensive*: all relevant issues are covered, the whole is complete
- *Consistent*: aspect models are free from contradictions and irregularities
- *Concise*: no superfluous matters are contained in it, the whole is compact and succinct
- *Essential*: it shows only the essence of the enterprise and its deep structure, it abstracts from realization nd implementation issues

6.3 The PSI theory

The Ψ-theory emerged in the 1990s out of the scientific community that is known as the Language-Action Perspective [86]. It consists of four axioms (**operation**, **transaction**, **composition**, **distinction**) and the **organization theorem**. The overall goal of the Ψ-theory is to extract the essence of an organization from its actual appearance. Since DEMO sees the organization as a system of socially interacting actors, the methodology is theoretically based on the PSI theory. Understanding it is a crucial step in learning DEMO modeling, therefore this section describes briefly each of the axioms, as presented in [32].

6.3.1 The Operation Axiom

The operation axiom states that the operation of an enterprise is constituted by the activities of actor roles, which are elementary chunks of authority and responsibility. The actor roles are fulfilled by subjects, who can perform two kinds of acts: **production acts** and **coordination acts**, and these have definite results: **production facts** and **coordination facts**.

A **coordination act (C-Act)** is an act by which a **coordination fact (C-fact)** in the **coordination world (C-world)** is created. By performing C-acts, subjects enter into and comply with commitments towards each other regarding the performance of production acts. C-act is an act performed by one actor called the performer, and directed to another actor, called the addressee. Acts can further be divided into **intention acts** and **proposition acts**. This concept is displayed in figure 6.2.

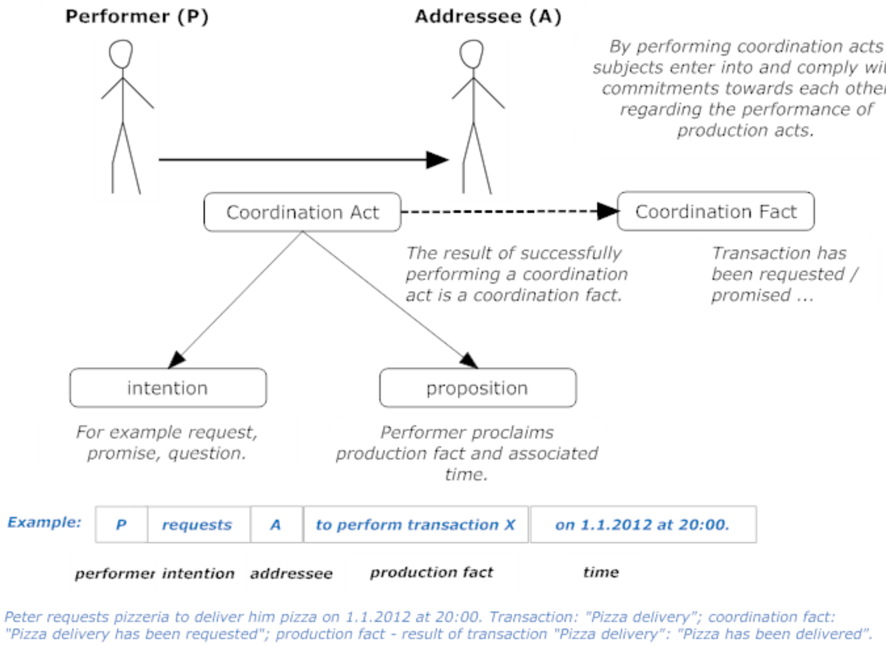


Figure 6.2: The operation axiom: relation of performer and addressee, coordination act and fact

A **production act (P-act)** is an act by which a **production fact (P-fact)** in the **production world (P-world)** is created. By performing P-acts, the subjects contribute to bringing about goods or services that are delivered to the environment of the enterprise. C-acts are always, either directly or indirectly, about production acts and production facts, which can further be divided into material or immaterial.

Actors are the active elements of an enterprise, who operate autonomously and deal with agendum according to the existing action rules. By specifying responsibility, authority and competence, the operation axiom is related to common organizational theories. Competence is the ability of a subject to perform particular P-acts as well as corresponding C-acts. Based on a competence, actors have authority, which they are expected to exert in a responsible way.

Based on a **competence**, you are given **authority**; if you are given authority, you have a **responsibility**, as displayed in figure 6.3.

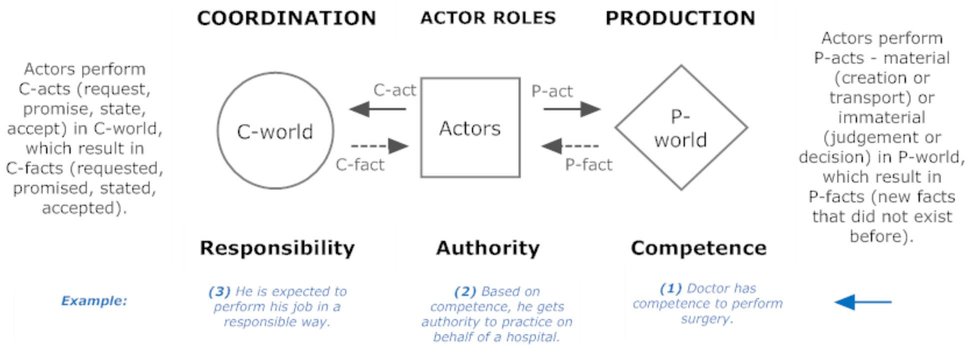


Figure 6.3: The operation axiom: relation of performer and addressee, coordination act and fact

6.3.2 The Transaction Axiom

The transaction axiom states that coordination acts are performed as steps in universal patterns, called transactions. Every new, original P-fact is a result of a successful transaction. Transactions always involve two actor roles (initiator and executor) and are aimed to achieve a result (P-fact). A transaction consists of three phases: the **order phase (O-phase)**, the **execution phase (E-phase)** and the **result phase (R-phase)**. The practical relevance in transaction axiom lies in detecting all C-acts, even those, that are performed tacitly. Steps are displayed in figure 6.4, notation used for transaction pattern is in Appendix C.

The basic transaction pattern

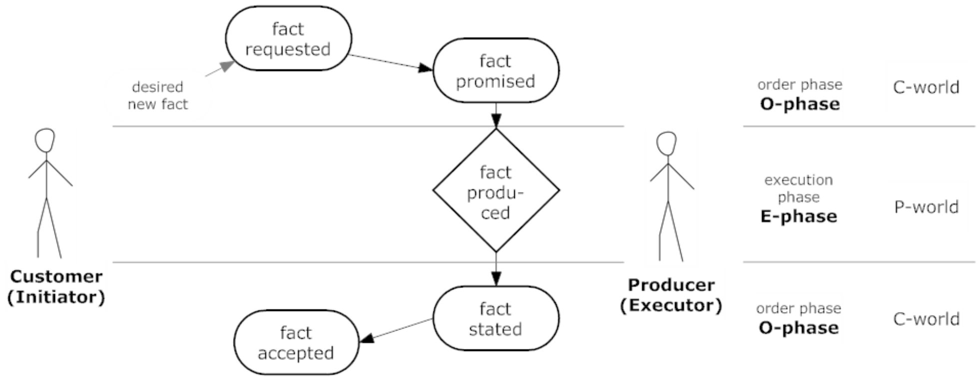


Figure 6.4: The Transaction pattern: steps in one transaction

In the order phase, request and promise are performed. The Initiator (customer) requests a P-fact, which is created as a result of a transaction. The executor makes a promise to create this P-fact. In the execution phase, the execution is performed which results in creating the P-fact. In the result phase, the executor states that the fact has been created and the initiator accepts the result.

The standard transaction pattern

Some situations might get more complicated. In some cases, the executor cannot promise creating the fact, so he declines it. Similarly, the initiator cannot accept the created fact, so he rejects it. There are three reasons for rejecting or declining, which are called validity claims (namely claim to truth, claim to justice or claim to sincerity) and are based on Habermas' theory of communicative action.

Cancellation patterns

Cancellation happens when either the initiator or the executor want to revoke an act. There are four cancellation patterns, one for each transaction step in the C-world. Cancellation of request and cancellation of acceptance would be done by the initiator, cancellation of promise and cancellation of state by the executor.

6.3.3 The Composition Axiom

How P-facts are interrelated is defined by the composition axiom. It **says that every transaction is enclosed in some other transaction, or**

it is a customer transaction of the organization, or it is a self-activation transaction. One transaction may consist of other transactions. Self-activation is a solution for periodic activities, like control activities. The transaction axiom provides basis for the definition of business process, by which is meant a collection of causally related transaction types, where the starting step is performed by an internal (self-activation) or external actor role.

6.3.4 The Distinction Axiom

This axiom serves to separate concerns, and therefore is called the distinction axiom. It states that there are three distinct human abilities playing role in the operation of actors, called **performa**, **informa** and **forma**, as displayed in figure 6.5. The forma ability concerns the form aspects of communication and information. The informa concerns the content aspects of communication and information. The performa concerns bringing about new, original things/facts, directly or indirectly by communication.

For one ontological act, we have to perform more infological acts, and for one infological act we have to perform more datalogical acts. This disctinction therefore offers a significant reduction of the complexity of the process model, in which only ontological acts are modeled.

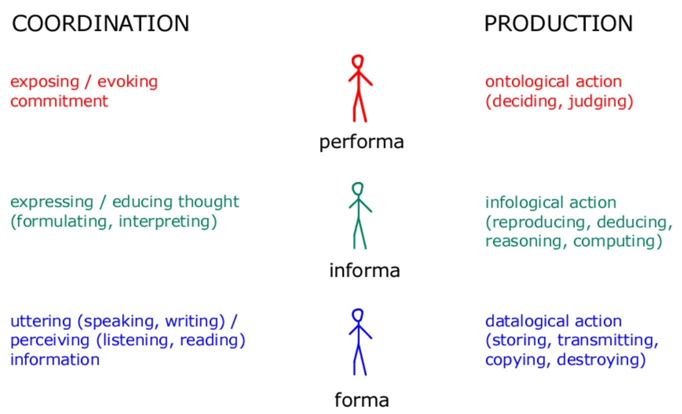


Figure 6.5: The Distinction axiom: performa, informa and forma levels

6.3.5 The Organization Theorem

The organization theorem (figure 6.6) states that an enterprise is a heterogeneous system that constitutes of three systems: **B-organization**, **I-**

organization and **D-organization**. The lower tier supports the upper one and there is nothing above the ontological level.

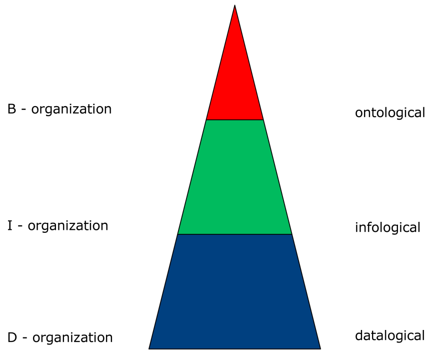


Figure 6.6: The three organizations according to the Organizational theorem

6.4 Modeling with DEMO

In this section, firstly a short description of elementary modeling elements is provided, followed by a description of each of the four DEMO's aspect models, which is based on [32]. The aspects models can be organized in a structure as displayed in figure 6.7, where the lowest model is the most detailed one, and the top one the most abstract one. The triangle is the top part of the triangle displaying the structure of all organizations, so it covers the ontological level. Some of the aspect models consist of more than one model; the structure of all the models is presented in figure 6.8. The chapter is finished by a sequence of steps of creating a DEMO model (guidelines).

6.4.1 Elementary elements

All elements used in DEMO models are described in corresponding aspect models. The two core elements in DEMO are **Ontological transaction** and **Actor role**.

Ontological transaction

The Ontological transaction involves actions that happen on the ontological level, as described by the Distinction axiom. Those involve bringing about the facts that did not exist before, making decisions, or transporting physical elements. Completion of a transaction, in a way that is described by the transaction axiom, results in a new original fact, called the P-fact.

Actor role

The two actor roles, the initiator and the executor, play an important role in DEMO modeling, as each transaction needs to have exactly one initiator and one executor. On the implementation level, one person can (and often does) possess more actor roles.

6.4.2 DEMO's Aspect models

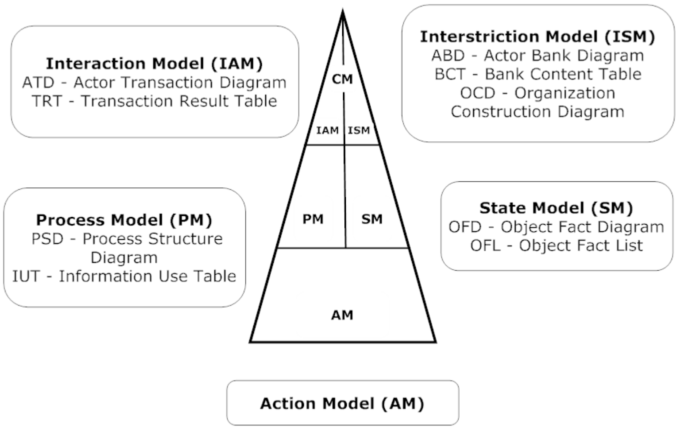


Figure 6.7: Structure of the DEMO's aspect models

Construction model (CM)

The Construction Model consists of the Interaction Model (IAM) and the Interstriction model (ISM). The CM specifies the construction of the organization - its composition, environment and structure. It shows all identified transaction types and associated actor roles, as well as information links between actor roles and information banks. Notation used in the CM is in Appendix C.

6.4.2.1 Interaction Model (IAM)

The Interaction Model shows the boundary of an organization and transaction types with identified actor roles – the initiator and the executor. It consists of one table and one diagram:

- **Transaction Result Table (TRT)** describes the identified transaction types and corresponding result types.
- **Actor Transaction Diagram (ATD)** shows relations between actor roles and transactions, includes markings of executor and initiator actor roles and organizational boundary.

Relevance of the IAM: *The IAM is the most compact ontological model of an enterprise. The main identified benefits are:*

1. *It shows the boundary of the organization, as well as the interface transactions with actor roles in the environment. With a single glance it is possible to see the customer (initiator) and supplier (executor), which makes IAM suitable for strategic alignment.*
2. *The wholeness of transaction pattern facilitates the attention to customer care. Emphasis is put on the fact that taking customer orders, satisfying them, and delivering the result to the customer are essentially one indivisible responsibility.*
3. *It shows the ontological units of competence, authorization and responsibility, which might offer insight into identification and classification of organizational functions.*

Interstriction Model (ISM)

The Interstriction model shows passive influence between actor roles. It is based on the IAM, to which the information flow is added. It contains two diagrams and one table:

- **Actor Bank Diagram (ABD)** shows relation (information links) between actor roles and information banks and actor roles and transactions. In ABD only information links are included.
- **Organization Construction Diagram (OCD)** combines the ABD and the ATD. It takes the ATD and only adds information links from the ABD to elements that are not yet connected in the ATD.
- **Bank Contents Table (BCT)** specifies the fact banks in which the elements of object classes and the instances of fact types and result types from the SM are contained.

Relevance of the ISM: *The ISM shows the complete "passive" structure of the system - the information links between actor roles and banks. It also shows external banks to which the enterprise needs to have access. Due to that, it has 3 following applications:*

1. *It provides background for flowcharting the existing information system and other ICT applications in an enterprise.*

2. *The abstraction in the ISM from the particular way in which the actor role gets the information needed, provides new, but very appropriate insight into the relationship between the actor role and needed information.*

3. *The ownership of data is made fully transparent - every fact is the result of a transaction, where two actors are involved - initiator and executor. The executor is responsible for executing the transaction in a right way. The initiator requests the production and becomes the first owner of the fact.*

6.4.2.2 Process Model (PM)

The Process Model contains a specific transaction pattern for every transaction type in the CM. It also shows the causal and conditional relationship between transactions defined by the CM. The PM is the specification of the state space and the transition space of the C-world. C-result and its causing C-act are collectively called a process step. Notation used in the PM is in Appendix C.

The Process Model contains one diagram and one table:

- **Process Structure Diagram (PSD)** provides structure of each process, shows process steps for every transaction and relationships between them. Steps that are not included in the PSD are not allowed. Normally, the disagreement patterns and the cancellation patterns must be included. The PSD of a business process should be understood as the complete specification of the steps in a business process that an enterprise wants to monitor or control. The PSD is the right starting point for designing the workflow support systems.

- **Information Use Table (IUT)** specifies for every object class, fact type and result type from the SM, in which steps of the PM are used its instances. It can only be created once the SM is produced.

Relevance of the PM: *The PM shows the deep structure of the business processes in an enterprise, independent of their implementation, and has a following application:*

1. *It abstracts from material aspects, both from real material things that may be produced or transported and from forms and files that are used for communication between the participants in the business processes.*

2. *From the PSD, it is quite straightforward to map to EPC or Petri Net. Therefore the PM is an ideal starting point for the purpose of programming a workflow management system.*

3. *It shows clearly that a component transaction may be optional or can be made optional.*

4. *It is suited to forward the discussion about the assignment of organizational functions to actor roles.*

5. *It is a useful starting point for requirements engineering regarding the development of information systems. The model leaves no room for unnecessary requirements, while at the same time guarantees that nothing will be forgotten.*

6. *It is a suitable starting point for developing Use Cases.*

6.4.2.3 State Model (SM)

The State Model specifies the state space of the P-world – object classes, fact types, result types, ontological existential rules. It is directly based on the AM, which makes it an objective model – only the information items that are relevant for the operation of an organization are included. Notation used in the SM is in Appendix C. State Model consists of one diagram and one table:

- **Object Fact Diagram (OFD)** shows the relation between object classes and declaration of result types.
- **Object Property List (OPL)** describes object classes. For each object class it also describes corresponding properties and their scale. For derived fact types, derivation rules are included.

Relevance of the SM: *The SM is the source of ontological knowledge about the production world, with a following application:*

1. *It is a starting point for developing and maintaining data dictionary of an enterprise.*

2. *It is structured in chunks around the main object types (variables in the result types of the distinct transaction types), which facilitates the business-component based design of databases.*

3. *The connections of the result types with the transaction types in which they are created, provides the basis for a sensible discussion of the issue of data ownership.*

6.4.2.4 Action Model (AM)

The Action Model (AM) specifies the action rules that serve as guidelines for actors in dealing with their agenda. It is the most detailed and comprehensive aspect model, from which the other models can derive. It is also atomic on the ontological level. The AM, in comparison to previous models, contains neither a table, nor a diagram. The action rules are described in a pseudo-algorithmic language and specify what is done on requested, on promised, on stated and on accepted. Conditional links from the PM are modeled in the AM as a normal agenda. Action rules are enclosed by an **on-no** bracket pair, conditions in an **if-fi** bracket pair, else-if by the symbol "◊" and repeated actions are enclosed in **do-od**.

Relevance of The AM: *The AM helps with creating a correct interstriction model and state model. The complete and consistent set of action rules helps with information system development and job descriptions (actor role fulfillments). The AM provides a full account of essential operational decisions in the enterprise, leaving out non-essential matters. The essential business rules are the remainder of filtering out the datalogical rules and the infological rules.*

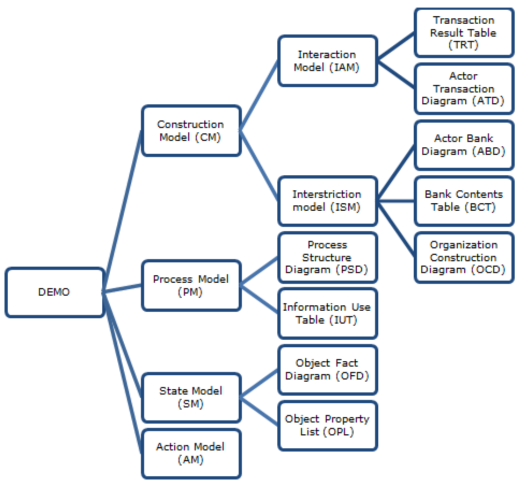


Figure 6.8: All diagrams and tables in DEMO's aspect models

6.4.3 Guidelines for constructing a DEMO model

Construction of some of the models is dependent on other models, unless one wants to refer back to the description of an enterprise all the time.

Guidelines for creating DEMO model are not clearly included in the book about DEMO, hence it would be practical to know a sequence of steps in creating a DEMO model, therefore methodological guidelines are created and briefly summarized in this section. It is based on the information about the DEMO's aspect models as presented in [32] and [86].

The first step in creating a DEMO model, based on the description of an enterprise, is identifying all ontological transactions. They are summarized in the *Transaction Result Table*. After identifying the actor roles, the *Actor Transaction Diagram* can be created. Next can be produced the *Process Structure Diagram* followed by the *Action Rules Specification* (Action Model). Then construction of the State Model, the *Object Fact Diagram* and the *Object Property List*, comes up. The *Information Use Table*, which is the second part of the PM, can be produced after completion of the SM. Lastly, the Interstriction Model enhances the Interaction Model with an information flow. It is presented in the *Actor Bank Diagram* and the *Bank Contents Table*. The *Actor Bank Diagram* (part of the ISM) can be drawn as an extension of the *Actor Transaction Diagram* (part of the IAM). Together they constitute the so-called *Organization Construction Diagram*, which is said to be a part of the ISM.

The guidelines for creating a full DEMO model (including all diagrams/tables), based on a description of an enterprise, can be summarized in following steps:

1. *The Performa-Informa-Forma analysis* - classifying the knowledge into ontological, infological and datalogical, according to the Distinction axiom, with the goal of identifying all ontological transactions.

2. *The Coordination-Production analysis and Actor roles analysis* - the act are classified into P-acts and C-acts and actor roles are identified.

3. *The Transaction pattern synthesis* - for every transaction type, the result type is formulated, and transaction pattern steps defined based on C-acts identified in previous step. *Construction of the TRT*.

4. *The Result structure analysis* - according to the Composition axiom, the structure of results is determined - an executor of one transaction may be initiator of others, which need to be completed prior to execution.

5. *The Construction synthesis* - for each transaction type, initiating and executing actor roles are identified. One actor role may be initiator to unlimited number of transaction, but executor to only one.

6. *The Organization synthesis* - a definite choice of what is an internal and what is an organizational transaction. *Construction of the ATD.*

7. *Construction of the PSD (PM).*

8. *Conditions, constraints and action rules identification* - based on the description, all action rules are identified. Based on them *construction of the AM.*

9. *Construction of the PFD and OPL* - based on the AM and analysis of object classes and property types the OFD and OPL, parts of the SM can be constructed.

10. *Construction of IUT* - based on the SM, the IUT, last part of the PM can be constructed.

11. *Identification of information flows* - based on the identified information flows and the IAM, *construction of the ABD, BTC and OCD (ISM).*

6.5 Integration of B/I/D organizations

Having read about the PSI theory and DEMO's aspect models, one understands that the main point of DEMO lies in modeling on the ontological level and abstracting from implementation. It would make sense, if the three organizations *(B, I and D)* would be in some way connected.

For one ontological transaction, there are at least two infological transactions, and for each infological transaction there are more datalogical transactions [86]. The explanation of how the three organizations are linked together, is missing in the book describing DEMO [32]. However, there is a paper written by Jong [51], where he explains the integration aspect between **B/I/D organizations**. To comply with the rules set in the DEMO methodology, the initiator and executor of a transaction must be from the same category (I-actor can only initiate I-transaction, D-actor can only execute D-transaction). The integration is therefore done by a human being in a following way: a *B-actor is able to shape into an I-actor and an I-actor is able to shape into a D-actor by the cohesive unification of human being.*

One task, which is part of a process modeled on an ontological level, can consist of multiple tasks on other (lower) levels, as displayed in figure 6.9.

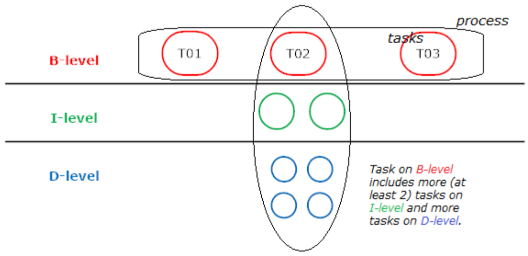


Figure 6.9: Integration of B/I/D organizations

6.6 Advantages of DEMO

The main advantage of the DEMO over other popular modeling approaches lies in its ability to master complexity of current enterprises and enterprise changes [15]. That is done by reducing the size of the models by only focusing on the essence of the enterprise, which is achieved by abstracting from technology and from all transaction kinds of which the result is informational or documental [34].

According to Land and Dietz [77] the underlying theory, namely the transaction and distinction axioms of the PSI theory offer each at least 70% reduction of complexity of the DEMO's Construction Model. By focusing only on the ontological level and incorporating the use of transactions, where by an ontological transaction, always the same sequence of steps (the transaction pattern) is meant, the total reduction of the model's size amounts to over 90%, while at the same time the represented ontological essence of enterprise contains all relevant elements [34].

With a profound theoretical background, it has the ability to capture the social interaction among human beings, while at the same time, the created ontological model is coherent, comprehensive, consistent, concise and essential [32]. In practice, this means that all essential knowledge about the organization, its operation and construction, is included in the DEMO model. Based on the description of an organization, there is only one way how to create the DEMO model, making the result unambiguous. DEMO's transaction axiom also helps to capture all communication steps, even those performed tacitly. The created model gives a holistic and implementation-independent view of an enterprise [77].

6.7 Application of DEMO

The main difference between the DEMO methodology and other process modeling techniques is, that DEMO saptures processes of an organization on a different level with total abstraction from implementation. DEMO, however, needs to be supplemented by, and connected with strategically and functionally oriented models, with infological and datalogical aspects, with implementation oriented process and ICT models. Three main areas where DEMO can be used were identified, based on literature search. Each of them is described below.

Enterprise and organizational engineering

Modern enterprises are growing in complexity and they extensively involve human interaction. To deal with complexity, the DEMO methodology fully abstracts from implementation and only includes the ontology of an enterprise. That is especially useful for enterprise transformation projects as it makes it easy to compare multiple design options at an enterprise level [77]. The human interaction is covered by the PSI theory. Since the DEMO model does not describe only the construction, but also the operation of an enterprise, it can be used for business process (re)design and improvement [16].

Implementation of an organization

The DEMO allows to model an enterprise with abstraction from its technological implementation. By implementation of the organization is understood making operational of the organization's realization by means of technology [32]. According to the organizational theorem, each level of organization (B/I/D) modeled in DEMO can be viewed at as a separate organization, which is the case not only for the construction of an organization but also for operation. The operation is in current enterprises always supported by ICT systems, therefore each organization is supported by different types of ICT systems, as displayed in figure 6.10.

In terms of support for production acts, D-applications run on hardware and include all generic software, like text processors, operating systems or data base systems. I-applications are put on top of the D-applications. They cover the Management Information Systems that provide information about an enterprise. B-applications are Decision Support Systems and are positioned on top of the I-applications [32].

ICT applications can also be used to support coordination acts. D-applications would include networks systems or e-mail systems. I-applications are usually referred to as Work Flow Systems, and Business Process Management Systems primarily aim to support the B-organizations [32].

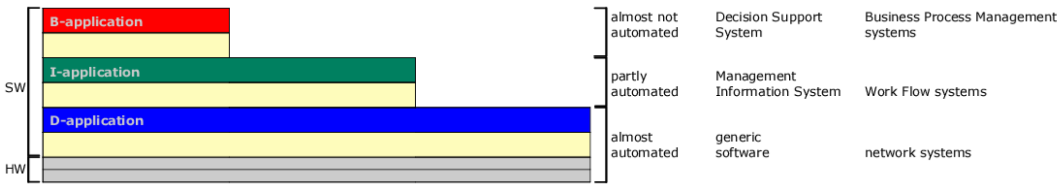


Figure 6.10: Role of ICT in each (B/I/D) organization

Software Engineering

DEMO models can be used as a starting point for software development. According to Barjis [14], if a business process model captures process flow, all core activities, their order and initiators and executors of each, it should be a significant step towards increasing likelihood of adequate software system design. The DEMO model captures all this required information. As investigated by Shishkov and Dietz [90], the DEMO's transactions are straightforwardly mappable into Use Cases. Those reflect essential behavior, including actors that are also identified by the DEMO methodology.

6.8 Simulation

As advantages of simulation have been mentioned in chapter Chapter 3, it seems clear that for business process (re)design it would only be beneficial if the modeling methodology included construction of a simulation model. DEMO is the methodology for (re)designing and (re)engineering organizations and its business processes, yet its inability to simulate the created model may be considered as one of its downsides: it's because all the aspect models are static and therefore do not lend themselves for simulation.

It would add a significant value to the DEMO methodology if models were further simulated. There are two approaches that can be undertaken: (1) translate the DEMO model of an organization into another simulation model, ensuring no conceptual aspects of the model, that would have an influence on the results of a simulation, are neither omitted nor altered by this translation; (2) extend the DEMO methodology so that it would support simulation. This choice is justified, and a solution described in Chapter 7.

Chapter 7

Translating the DEMO model into a Petri net simulation model

7.1 Introduction

As concluded in the Chapter 6, the DEMO methodology does not include simulation. It would, however, add a significant value to it, if the DEMO models are further simulated. The aim of this chapter is to describe a method of translating a DEMO model into a Petri net simulation model and justify the choice of a Petri net. The method is demonstrated on the case example in the Chapter 8.

7.1.1 Choice of an approach

The two approaches that can be undertaken are:

1. Translate the DEMO model of an organization into another simulation model, ensuring no conceptual aspects of the model, that would have an influence on the results of a simulation are neither omitted nor altered by this translation

2. Extend the DEMO methodology so that it would support simulation.

The DEMO models have been used as a starting models for various purposes, for example for deriving use cases from business processes [89], or for process modeling in software systems design, where particularly the DEMO's transaction concept has been used [14].

In both cases, DEMO was taken as a starting point. Either the principles were used further or the model was translated into another model.

This, together with the possibility to use already existing well developed simulation techniques, are the reasons for choosing the first of the mentioned approaches – **translate the DEMO model into another simulation model**.

7.1.2 Choice of a simulation technique

Prior to translating the DEMO model into a simulation model, a simulation technique has to be adopted. In was concluded in Chapter 3, that the Discrete Event Simulation is suitable for simulating business processes and workflows.

Among available modeling techniques for discrete event dynamic systems, the Petri net is one of the most often used for modeling workflow systems [85]. The suitability of Petri nets for modeling and simulation of workflows and business processes has been discussed by multiple researches.

Aalst [5] summarizes following three reasons for using a Petri net based workflow system:

1. formal semantics despite the graphical nature
2. state-based instead of event-based
3. abundance of analysis techniques.

Adam et al. [6] concludes that the use of the Petri net is an effective tool for modeling workflows at a conceptual level, prior to analyzing them. That is confirmed by Desel and Erwin [31], who see the advantage of Petri nets in the fact that they can be directly executable, so the models can be easily used to examine the behavioral aspects of the modeled system during a simulation.

Developing a method of translating the DEMO model into the (high-level) Petri net model would take the advantage of both – the DEMO methodology, its completeness and understandability for users, and the (high-level) Petri net, its formal semantics and proved suitability for a business process simulation.

The decision was made to use Petri net, therefore the focus is on building a Petri net simulation model. Since Petri nets are directly executable, Petri net models can easily be used to examine the behavioral aspects of the modeled system during a simulation [31]. According to the definition of a model, presented in Chapter 3, a ***Petri net model is a conceptual model, as well as a computerized model, and be called further in this chapter a simulation model***.

7.2 The DEMO methodology and a Petri net technique

In Chapter 3 was mentioned, that an important pre-requisite for creating a simulation model is knowing what information is needed about the process. This section analyzes the DEMO's aspect models, and what information is contained in each of the model. Following, an introduction into a Petri net technique is provided. The table of information needed to build a simulation model is compared with the information contained in the DEMO models and possibilities of a Petri net.

7.2.1 Information contained in the DEMO's aspect models

The table 7.1 summarizing the elements in the model, and their relation, and was gained based on analyzing the aspect models, as presented in [32].

7.2.2 Introduction to Petri Net modeling

Petri nets were first introduced by Carl Adam Petri in the 1970s. They have well defined mathematical foundation and an easy to understand graphical representation. The classical Petri net is a directed bipartite graph, which consists of places, transitions and directed arcs. Places are represented by circles (conditions) and transitions by rectangles (process steps). Two elements of a same type cannot follow [3] [85].

The classical Petri net allows to model states, events, conditions, synchronization, parallelism, choice, and iteration, but they do not allow to model data and time. Tokes represent objects that flow through the modeled system [3] [85].

Definition [50]:
Petri net is a triple (P, T, F), where:

- ***P*** *is a finite set of states, called places*
- ***T*** *is a finite set of transitions* $(P \cap T = \oslash\ )$
- ***F*** $\subseteq (P \times T\ )\ \ (T \times P\ )$ *is a set of arcs (flow relation)*

High level Petri net is a classical Petri net extended by 3 aspects: **color, time** and **hierarchy**. Color extension allows to model data, by adding attributes to tokens, which is called a value of a token. The value of produced tokens is then determined by the transitions, and can also play a role in decision points. Extension with time allows adding time (duration or delays) to places, arcs, transitions or tokens. By this, it is possible to model the temporal behavior of processes, and analyze the performance. Hierarchy extension helps to deal with complexity of the current processes, by allowing breaking complex Petri net into subnets [3] [85].

Definition [50]:

A Coloured Petri Net is a nine-tuple, CPN = (P, T, A, S, V, C, G, E, I), where:

- ***P*** *is set of places*
- ***T*** *is set of transitions*
- ***A*** *is set of arcs*
- ***S*** *is set of colour sets*
- ***V*** *is set of variables*
- ***C*** *is colour set function (assigns colour sets to places)*
- ***G*** *is guard function (assigns guards to transitions)*
- ***E*** *is arc expression function (assigns arc expressions to arcs)*
- ***I*** *is initialisation function (assigns initial markings to places)*

Basic modeling constructs include the 4 types of routings, displayed in figure 7.1. In case of **conditional routing**, based on the condition on the place, either **T1A** and **T2A** are executed, or **T1B** and **T2B**. In case of **parallel routing**, the branch is on transition and both **T2** and **T3** are executed in parallel. The Petri net models must be consistent, so for split on transition, the join must be on transition, and same way with split on place. This is normally ensured by the modeling tool, which checks the model consistency.

7.2.3 Information needed for simulation, DEMO and Petri Net

After analyzing the DEMO's aspect models (table 7.1), information needed for simulation (Chapter 3 table 3.3) and Petri nets, a table 7.2 summarizing these aspects was created. It also shows for each element/information in

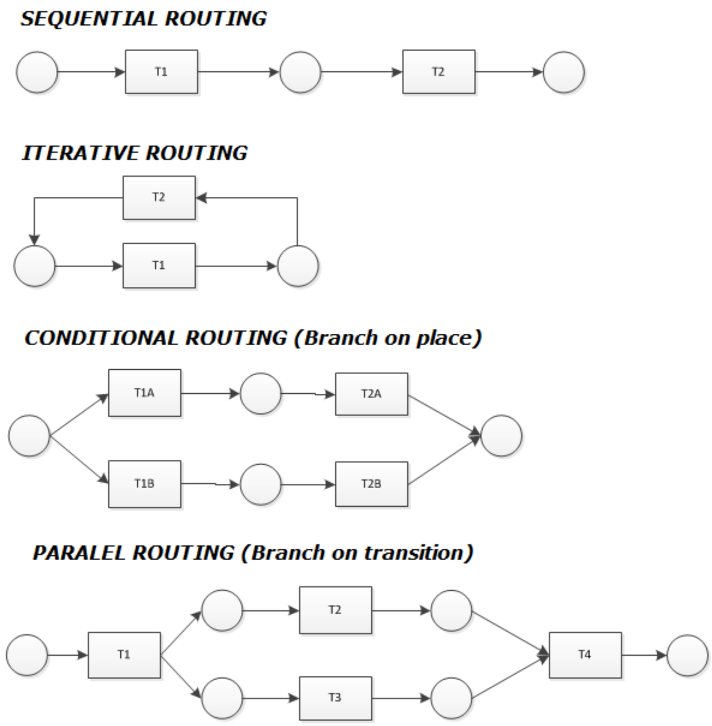


Figure 7.1: Types of routings in a Petri net

which DEMO's aspect model can be found. *Entities* in the first row are tokens that do not contain any data, and therefore we do not need to know their structure. By *resources* it is meant only the name of the actor roles, not resource availability - that is included in Performance measures.

All the information needed to construct a Petri net model is included in the DEMO model. It captures the structure of the organization and processes, but performance measures like execution times or waiting times, case generation scheme and resource availability are not included and would have to be specified in addition to the DEMO model in order to conduct performance analysis. Depending on *Decision rules for decision points*, either probability for taking alternative paths would have to be specified, or tokens flowing through the model would need to contain data according to which the decisions are made.

Aspect Model	Model	Type	Elements in the model	Relation of elements in the model
IAM	TRT	table	transaction type result type	Pair: transaction type + result type
	ATD	diagram	transaction actor role – initiator and executor organization's boundary initiator/executor links	Relation (link): initiator – transaction (initiator link) transaction – executor (executor link)
ISM	ABD	diagram	fact bank (P-bank) actor role transaction organization's boundary information links	Relation (information flow): actor role – information bank actor role – transaction
	OCD	diagram	fact bank (P-bank) actor role transaction organization's boundary information links initiator/executor links	Relation (initiator/executor link): actor role – transaction Relation (information flow): actor role – information bank actor role – transaction (if no initiator/executor link for this pair)
	BCT	table	object class, fact type or result type fact bank (P-bank)	Pair: object class/fact type/result type + fact-bank
PM	PSD	diagram	process step (rq, pm, ex, st, acc) links (causal/conditional) responsibility area actor roles	Relation between two process steps (links) Multiplicity of links (0..k)
	IUT	table	object class, fact type or result type process step	Pair: object class/fact type/result type + process step
SM	OFD	diagram	object class fact type result type scale essential laws (links)	Relation (essential law): object class – result type object class – fact type – object class fact type – scale
	OPL	table	property type object class scale derivation rules for derived fact types	Triplet: object class + property type + scale
AM		action rules	agendum that is being dealt with actions that can be taken conditional choices agendum to deal with: on requested, on promised, on stated, on accepted actions to be taken: request, promise, decline, execute, state, accept, reject	Specifies: Agendum + action(s) to be taken Agendum + conditional choice(s) between action(s) to be taken

Table 7.1: Overview of information contained in the DEMO's aspect models

<table>
<tr><th>Element / Information</th><th>PN</th><th>DEMO</th><th>Element in DEMO</th><th>Diagram in DEMO</th></tr>
<tr><td>Entities</td><td rowspan="4">YES (classical or high level)</td><td rowspan="4">YES</td><td>object class</td><td>IUT (PM)</td></tr>
<tr><td>Activities</td><td>transactions</td><td>ATD & TRT (IAM)</td></tr>
<tr><td>Routings (Control-flow)</td><td>conditional choices, action rules</td><td>PM (conditional / causal links), AM (action rules)</td></tr>
<tr><td>Resources</td><td>actor roles</td><td>ATD (IAM)</td></tr>
<tr><td>Decision rules for decision points</td><td rowspan="2">YES (high level)</td><td colspan="3">Described bellow</td></tr>
<tr><td>Performance measures</td><td>NO</td><td>–</td><td>–</td></tr>
</table>

<table>
<tr><th colspan="5">Decision rules for decision points:</th></tr>
<tr><th>Element / Information</th><th>PN</th><th>DEMO</th><th>Element in DEMO</th><th>Diagram in DEMO</th></tr>
<tr><td>Data (Entities must have specified attributes)</td><td rowspan="2">YES (high level)</td><td rowspan="2">YES</td><td>object class</td><td>OPL (SM)</td></tr>
<tr><td>Rules decision points</td><td>action rules</td><td>AM</td></tr>
<tr><td colspan="5">OR</td></tr>
<tr><td>Probability for taking alternative paths</td><td>YES (high level)</td><td>NO</td><td>–</td><td>–</td></tr>
</table>

Table 7.2: Availability of information needed for simulation

7.3 Method of translating the DEMO model into a Petri net model

By taking multiple different models in the DEMO and creating corresponding models in Petri nets the method of translating the DEMO model in a Petri net model has been developed. The method consists of modeling constructs, which take the typical situations and present a way of modeling the particular aspects in Petri net and in the DEMO. The modeling constructs were tested, using a free Petri net simulation tool called the CPN Tools [28], and demonstrated on the case example in Chapter 8.

The main input from the DEMO model is the PSD (Process Structure Diagram). The DEMO's Process Model contains a transaction pattern for every transaction identified in the Construction Model and shows the causal and conditional relationship between transactions. Since its main diagram - the Process Structure Diagram, is used to specify all allowed steps in a business process as well as their relations, it is the most suitable diagram for creating a Petri net simulation model. In a following section the modeling constructs of PSD are presented together with corresponding modeling constructs in the Petri net.

The execution phase in the Petri net is in some cases divided into few steps *(T0x e1, T0x e2)* to make the model more readable, and mainly to capture the situation when the actual execution needs to wait for conditional link from another transaction(s). The examples used for each of the situations are taken from the case example described in a following section.

Figure 7.2 displays the possible connections between the transactions – using either a **causal link** or a **conditional link**.

Causal link initiates new transaction from any of the steps *(rq, pm, st, ac)*. If initiated on accept, transactions are completed sequentially. In other cases, they are partially nested or nested, depending on the conditional link.

Conditional link indicates that one transaction step is waiting for a completion of another transaction step of a different transaction.

Partially nested transaction: *T02* is initiated within *T01* but not completed within *T01*. *T02* can be initiated with no conditional link, meaning *T01* execution continues immediately after requesting *T02*, or execution of *T01* may wait on conditional link from *T02 (rq/pm/st)*.

Nested (composite) transaction: *T02* is nested (or composite), if completion of *T02* is necessary to proceed with execution of *T01*.

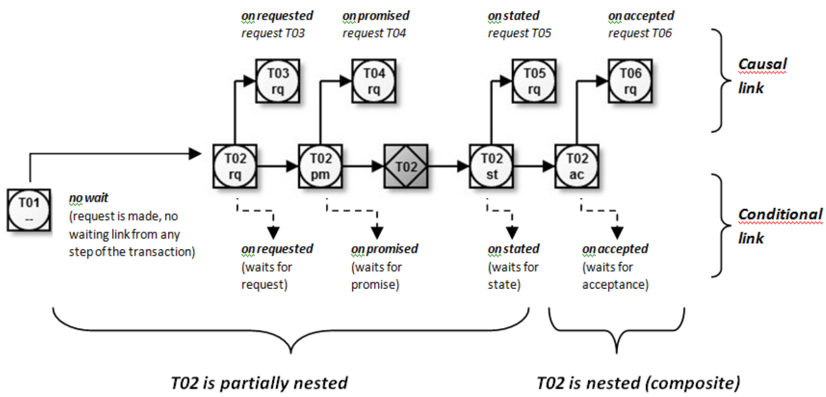
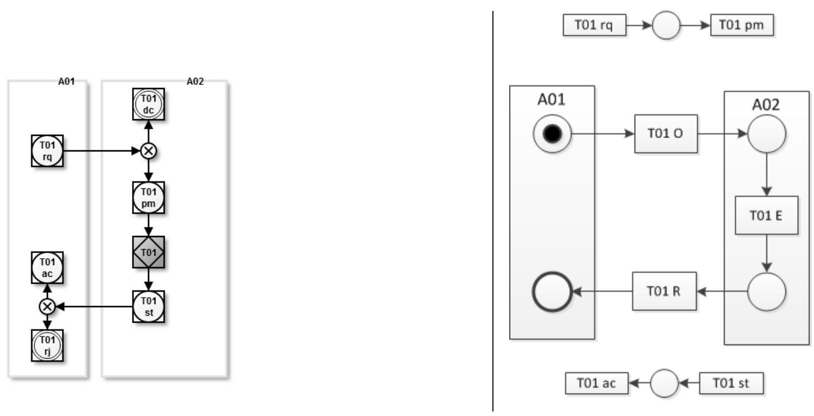


Figure 7.2: Relation of transactions in the PSD

7.3.1 One transaction – elementary patterns

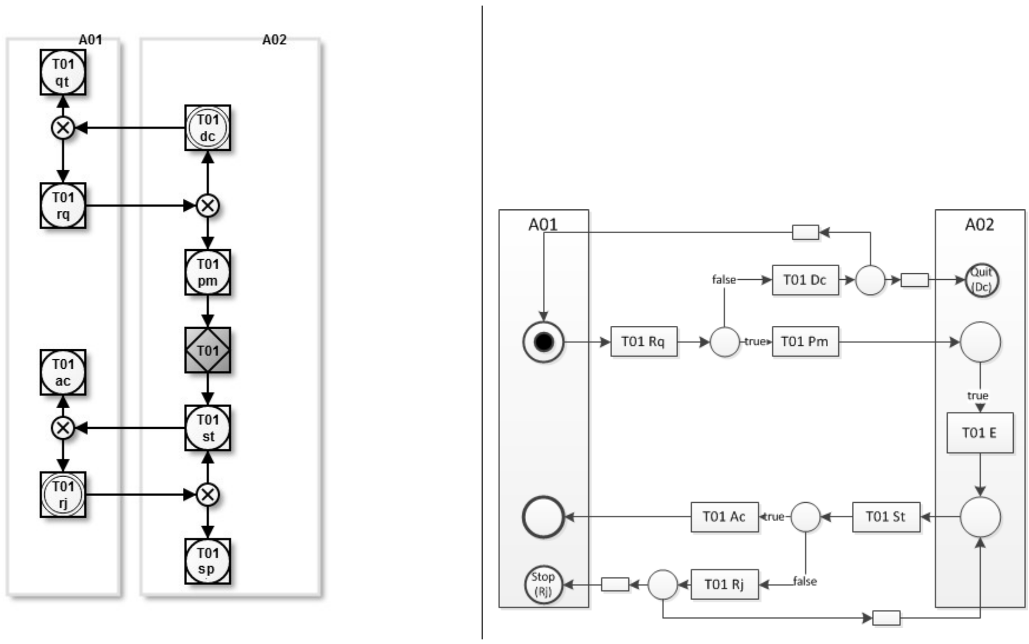
Basic transaction pattern

The basic transaction includes all steps of the transaction pattern: *request, promise, execution, state, accept*. *A01* and *A02* are the actor roles that perform the steps. Pair *request-promise* is in PN modeled together as an *Order phase* and pair s*tate-accept* as a *Result phase*. If distinction whether **causal** / **conditional** link goes from/to *rq* or *pm* (*st* or *ac*) needs to be made, *O (R) phase* will be modeled in detail using **hierarchy concept** of the Petri net.



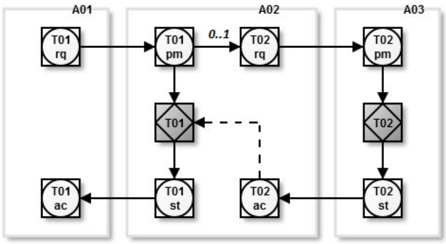
Standard transaction pattern

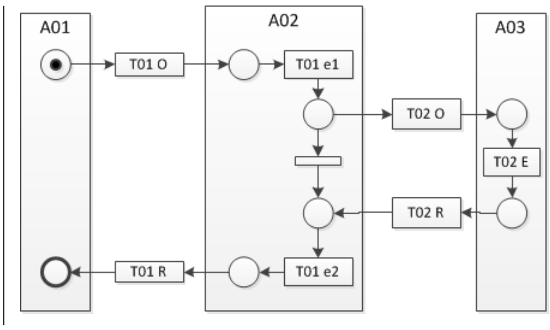
In the DEMO, a *request* can be followed either by *promise*, or by *decline*; a *state* can be followed either by *accept* or by *reject*. Rules for promising / declining and accepting / rejecting are specified in the Action Model, together with actions that follow when declined or rejected.



Optional transaction

In the DEMO, an optional transaction is indicated by writing ***0..1*** above the causal link. Transaction T02 is optional. (In this example, the execution of *T01* waits for completion of *T02*).

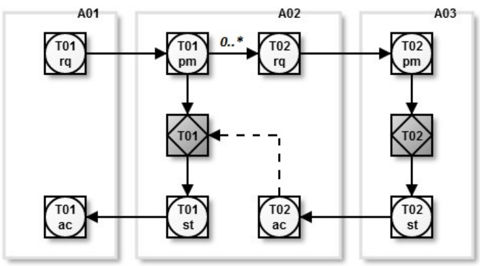




Multiple execution of a transaction

To indicate that a transaction can be executed multiple times, the DEMO uses expression ***0..**** (optional) or ***1..**** (is executed at least once) above the causal link. Transaction T02 can be executed multiple times.

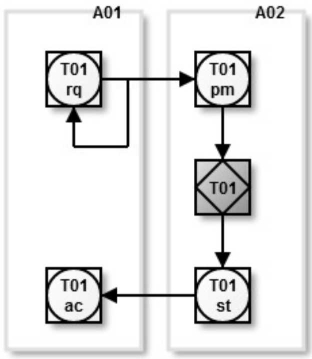
In this case, the Petri net model would depend on whether the multiple executions of T02 are sequential, parallel, or some combination. If all executions of T02 are done sequentially, in the PN we can use typical iterative routing construct. Parallel multiple execution of T02 can be modeled in the PN by assigning multiple tokens to the starting place of T02.

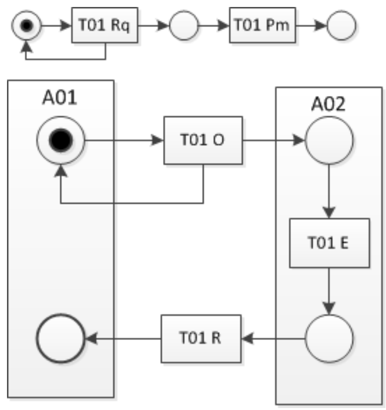


Self-initiated transaction

Transactions that repeat periodically are called self-initiated transactions. On T01 request, T01 is requested again, with a timestamp of the following execution, which is indicated by the loop.

Example: *T05: Stock control; Stock control is performed once a month.*





7.3.2 Two transactions

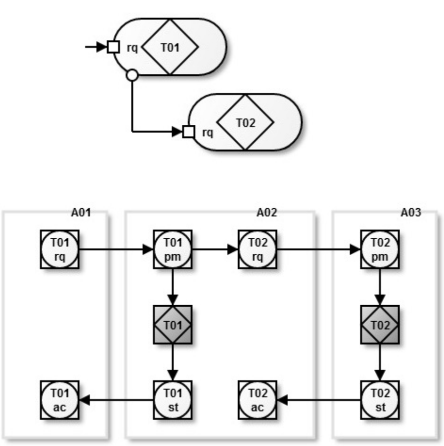
Two transactions can relate to each other in multiple ways: they can be **sequential** (T02 follows after the completion of T01), **parallel** (both T01 and T02 start at the same time) or one can be **nested** in the other. The term *"T02 is nested in T01"* means that T02 is initiated during T01 and may **(nested)** or may not **(partially nested)** be completed within T01, which is specified by the **conditional (wait) link** between the steps. Most often, T02 would be initiated on promise of T01 and the execution of T01 in case of nested transaction waits on link from T02 accept. Other situations are, however, also possible.

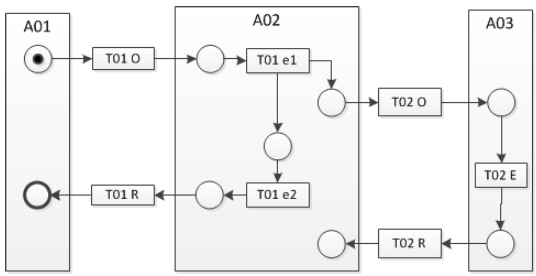
Bellow are summarized the modeling constructs, for the situation where T02 would be requested on *promise* of T01, and execution of T01 would wait on different steps of T02: *rq, pm, st, ac.*

Request & no wait

T02 is initiated during T01, but may be completed any time.

Example: *T01: Medical check-up; T02: Medical check-up payment. Imagine if Medical check-up does not wait for the completion of Medical check-up payment. On requested T08, T09 is requested and T08 continues straight away, without waiting for the completion of the payment.*





Parallel split on T01 e1 initiates T02, which can be completed any time.

Request & wait for completion of request (on requested)

T02 is initiated during T01, but may be completed any time. Execution of T01 is performed after T02 request has been completed.

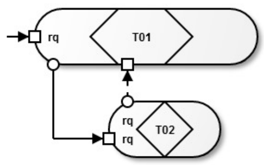
Example: *Similar to the previous case; T01: Medical check-up; T02: Medical check-up payment. Imagine if before executing T01 (performing the medical check-up), we need to be sure the request for payment (T02/rq) has been completed. This would be used for example in the situation where the request takes longer time, and we need to be sure of its completion before proceeding to execution.*

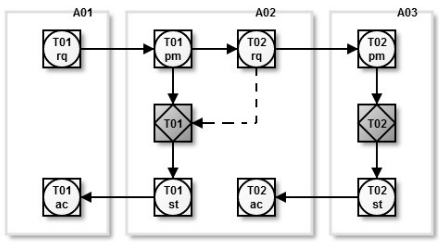
Request & wait for promise (on promised)

T02 is initiated during T01, but may be completed any time. Execution of T01 is performed after T02 promise.

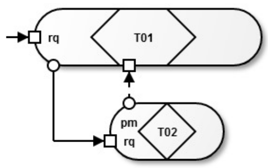
Example: *Similar to the previous case; T01: Medical check-up; T02: Medical check-up payment. Imagine if the medical check-up can proceed to execution as soon as the client promises the payment of the medical check-up fee.*

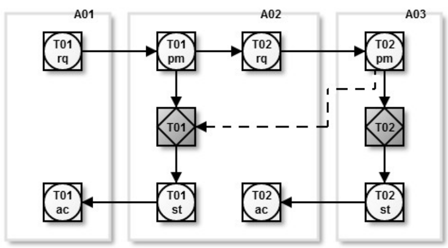
Request & wait for completion of request (on requested)



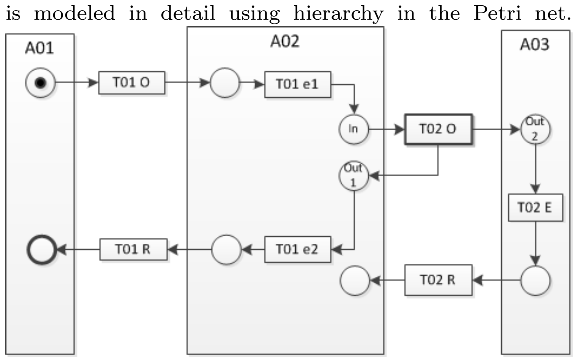


Request & wait for promise (on promised)

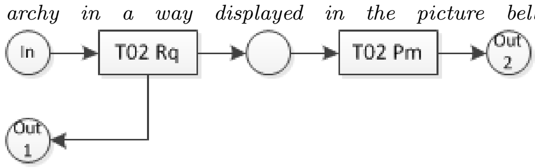




Wait link from *rq* and *pm* is modeled in the same way from the *O* transition. If distinction needs to be made, which is the case of wait link from *rq*, the *O* transition is modeled in detail using hierarchy in the Petri net.



*Parallel split on **T01 e1** initiates **T02**, which can be completed any time, but execution of **T01**, which is done in step **T01 e2**, waits for the completion of **T02 O**. To specify that a link goes from **rq** phase, **T02 O** would be modeled using hierarchy in a way displayed in the picture bellow.*



Request & wait for state (on stated)

T02 is initiated during T01, but may be completed any time. Execution of T01 is performed after T02 state.

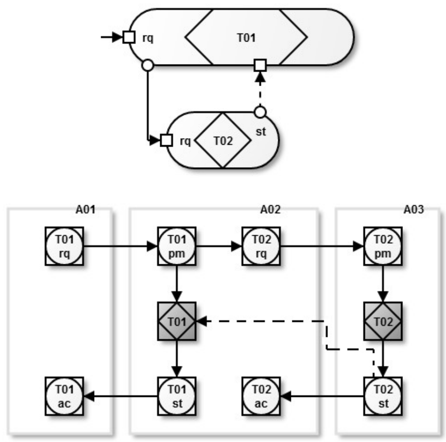
Example: *Similar to previous case; T01: Medical check-up; T02: Medical check-up payment. Imagine if the client's statement that he has paid the fee is sufficient for the execution of the medical check-up payment,. Because it was for example a bank-transfer, the medical clinic has not received it and therefore accepted it.*

Request & wait for acceptance (on accepted): Nested (composite) transaction

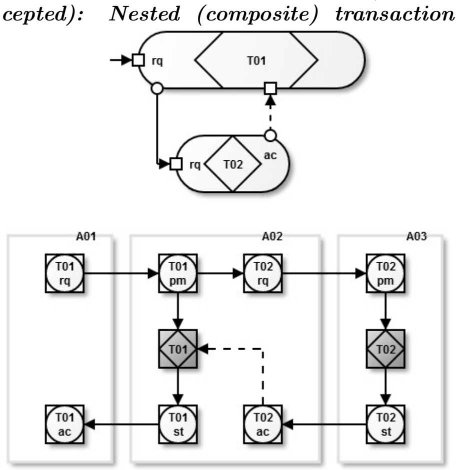
T02 is initiated during T01 and must be completed within T01, execution of T01 waits for acceptance of T02.

Example: *T01: Medical check-up; T02: Medical check-up payment. The payment must be completed and accepted before the execution of medical check-up.*

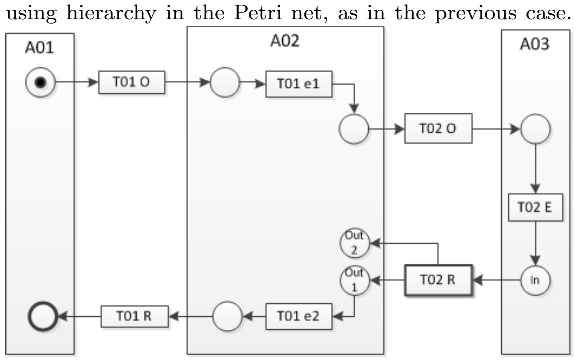
Request & wait for state (on stated)



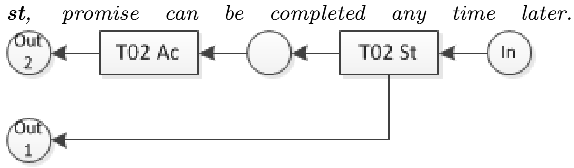
Request & wait for acceptance (on accepted): Nested (composite) transaction



Similarly to the previous case, wait link from *st* and *ac*, is modeled in the same way, from the *R* transition. If a distinction needs to be made, which is the case of a wait link from *st*, the *R* transition is modeled in detail using hierarchy in the Petri net, as in the previous case.



Parallel split on ***T01 e1*** *initiates* ***T02,*** *which should be completed before the execution of* ***T01,*** *in case of link from* **ac**. *In case of link from* **st,** *promise can be completed any time later.*



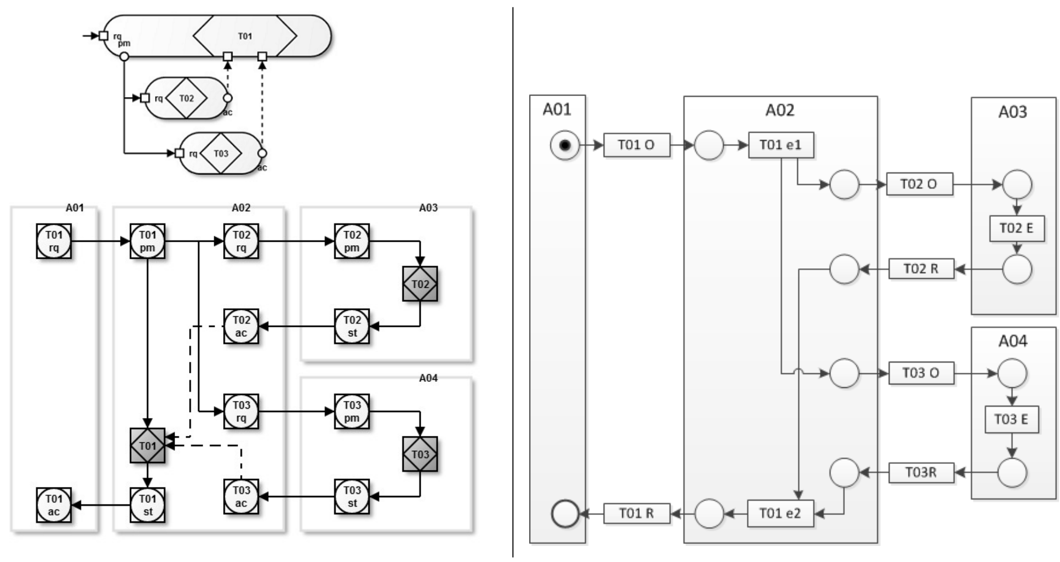
7.3.3 Three or more transactions

In case of three or more transactions, same situations as with two transactions can occur, but in addition to relation between the initiating transaction, and the (partially) nested transaction, the two (partially) nested transactions can be in various relationships. They can be executed in **parallel**, or **sequentially**, which would be defined by the conditional link between them, or as a **deep nested**.

Two nested transactions executed in parallel

Both T02 and T03 are initiated within T01 and must be completed within T01, however they can be executed in parallel – there is no causal link between them.

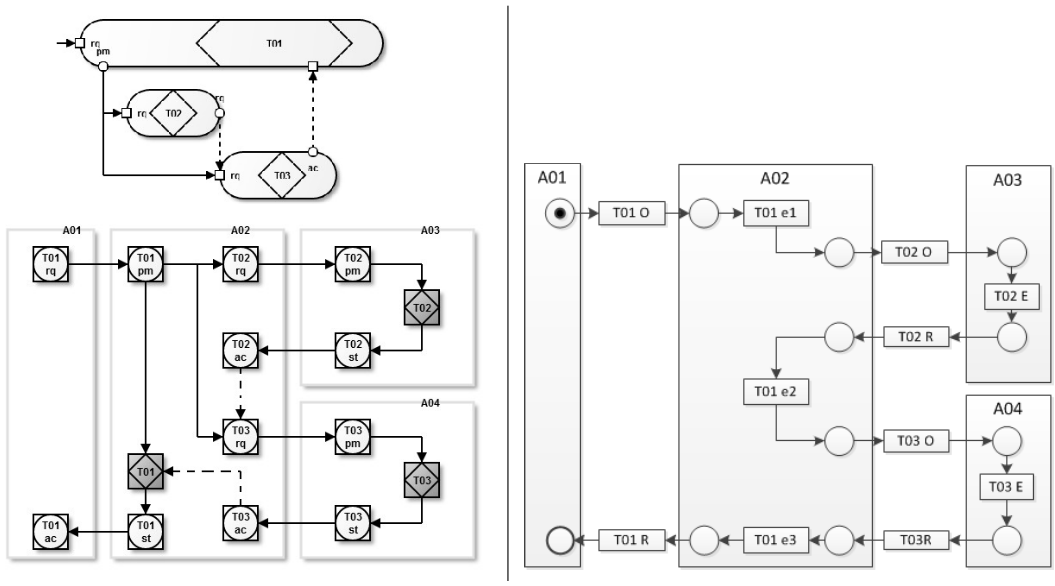
Example: *T01: Acceptance of applicant T02: Medical check-up; T03: Medical check-up payment. Imagine if the medical check-up (T02) and payment (T03) are requested at the same time (on promising T01), and do not depend on each other – may be executed in parallel. The actors, as displayed, might be two different people.*



Two nested transactions executed sequentially

Both T02 and T03 are initiated within T01, and completed within T01. There is a conditional link between them: T03 request waits for acceptance of T02.

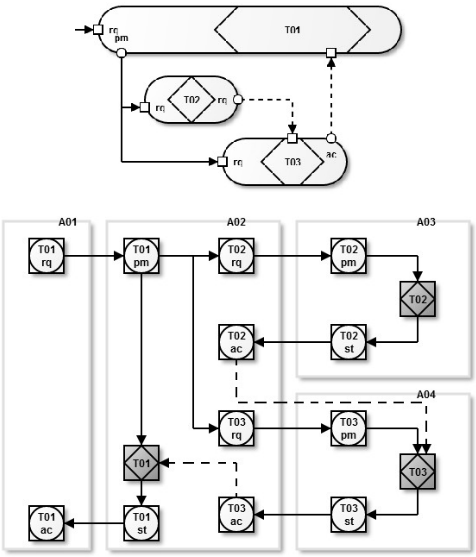
Example: *T01: Order completion; T02: Delivery; T03: Payment; During Order completion, two tasks have to be completed, in a sequential order – Payment is requested as soon as Delivery is accepted.*

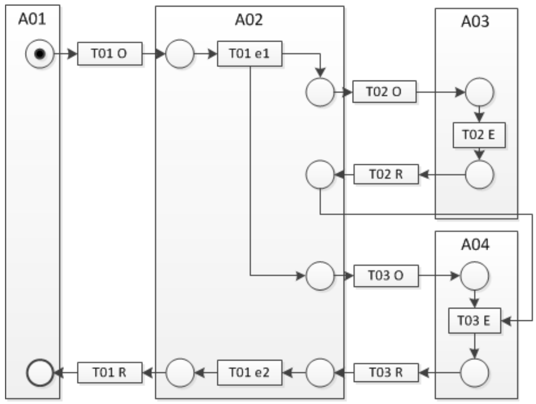


Two nested transactions initiated in parallel, but completed sequentially

The transactions have conditional link between them. Both T02 and T03 are initiated within T01, and completed within T01. There is a conditional link between them: T03 execution waits for acceptance of T02.

Example: *T01: Order completion; T02: Pizza preparation, T02: Pizza delivery; Pizza delivery is initiated immediately after the initiation of Pizza preparation, but its execution waits after the completion of pizza preparation.*

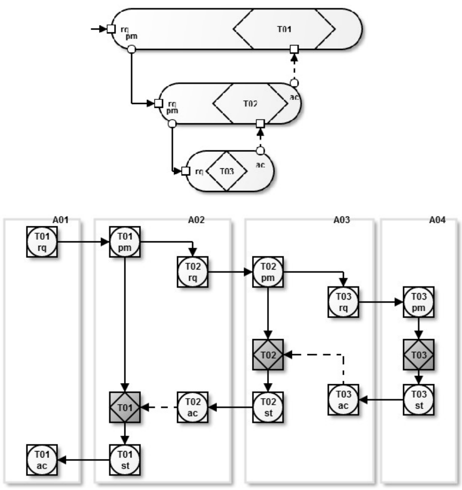


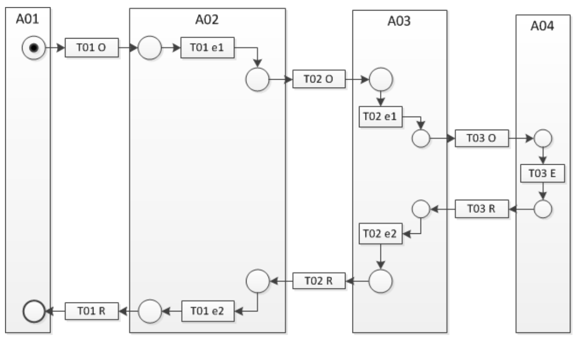


Deep nested transactions

T02 is initiated during T01, and must be completed before the execution of T01. T03 is initiated during T02, and must be completed before the execution of T02. That makes the order of completion of the transactions: (1) T03; (2) T02; (3) T01.

Example: *T01: Applicant acceptance; T02: Medical check-up, T08: Medical check-up payment; After paying for medical check-up, the medical check-up is executed. After completing the medical checkup, the applicant is accepted.*





7.3.4 Validation and verification

Validation

Validation confirms that the model is an accurate representation of a real system. When translating the DEMO model into a Petri net model, the most important is that no conceptual aspects have been omitted or altered by this translation, that would have an impact on the results of the simulation.

The method was developed by translating multiple case studies into a Petri net model, each covering various aspects, which allowed to identify the most common situations. The method covers all options for one transaction, and two and three transactions, and how they can relate to each other 7.2. Each modeling construct for each above mentioned situation was tested individually, by running the Petri net model and observing the flow of the tokens.

In the DEMO, some links are **conditional**, which are used to model waiting on a particular transaction. Those are in a Petri net modeled as a **normal links**. The result is the same, because the transition is enabled only when input tokens are available from all input arcs. *Request* and *promise* can be modeled together as an *order phase*, similarly *state* and *accept* as a *result phase*, but it was shown, that if necessary, the distinction may be done also.

So the Petri net is able to model both the **full transaction axiom**, exactly like included in DEMO, and both the **conditional links** and **causal links**, that are core connecters in the steps of the transaction pattern. This confirms that a Petri net is capable of modeling the fundamental aspects of DEMO.

Verification

Verification confirms that the model is working properly. It can be left to the tool, which was the case of CPN Tools here also. Verification checks reachability of all states and absence of deadlocks, confirming whether the model is working properly. The tool also automatically check the syntax correctness, like an alternating sequence of places and transitions, and splitting and joining or parallel and alternative paths.

7.4 Summary

The approach of translating the DEMO model into a Petri net model was chosen, as it has been proved in previous studies that Petri nets are a suitable tool for workflow modeling and simulation. The method of translating the DEMO model into the Petri net model consists of a set of modeling constructs of the DEMO's Process Structure Diagram, which is taken as the main input, and corresponding modeling constructs in the Petri net. The DEMO model contains all invariable information needed to build a simulation model, leaving out only the performance measures.

The obtained Petri net model may find utilization in:

1. **Studying the dynamic behavior of the system, which would help especially with validation of the modeled processes**

2. **Simulation for the purpose of performance analysis**

In the first case, the performance measures might be left out, and the classical Petri net would be sufficient. For the second usage the high-level Petri net is needed.

Chapter **8**

Case Study

This chapter includes a case study of a small organization. Firstly, the description of the organization is included, followed by the models in the BORM methodology, the BPMN and the DEMO methodology.

The models were completed using following tools:

- **BORM:** IzmanCASE [76]
- **BPMN:** Bizagi [19]
- **DEMO:** Xemod [73]
- **Petri net:** CPN Tools [28]

8.1 Case description: Take-away pizzeria

The take-away pizzeria Eat Fresh offers wide selection of pizzas for take-away and also delivers them anywhere in the town. The name Eat Fresh was chosen because pizzas are made only upon order. Eat Fresh is a chain, with branches located in many smaller towns. The rest of the text is a description of one of the branches.

Pizza ordering and delivery

Customer walks in and places an order at the counter or makes a telephone call. The menu, which is same for all branches, lies on the counter and is also available on the internet. The cashier writes down the name of the customer, selected items and calculates and writes down the total price. In case of delivery, she ticks a box "delivery" and writes down the address. Each order form has a unique number (order number) and is produced in three copies – white, yellow and blue. The cashier slides the yellow one through the hatch in the wall to the kitchen, where cooks take care of the order's preparation. If the order is for delivery, she hands the white copy to the transporter's room, where students, who are hired to deliver the ordered pizzas take care of it. The blue copy always remains with the cashier.

The cashier is always aware of what kinds of pizza are currently available, so she would tell the customer immediately when he is ordering, if the desired kind of pizza is unavailable. It happens only very rarely, that the cook is not able to fulfill the order completely, because of missing ingredients. In such a case, he puts had through the hatch and notifies the cashier of his problem and returns the yellow copy. If the customer is present in the shop, the cashier informs him about the situation and according to his choice modifies the order. If the customer, however, is not present in the shop, she changes the order by herself. The order number however stays the same.

As soon as the order is ready, the cook slides the pizza(s) in boxes through a hatch in the wall either back to the cashier, or to the transporters room, if the box "delivery" is ticked, together with the yellow order form. Cashier takes the pizza, finds matching blue form, calls the customer, hands him the pizza(s) together with the white form as a receipt and requests and waits for the payment. The blue copy of an order-form is kept for the pizzeria's record.

In case of delivery, a student takes pizza(s) and leaves with white and yellow copies. He/she hands the order to the customer together with the receipt (white copy). He/she requests and waits for a payment. After customer has paid and signed the yellow copy, the student goes back to pizzeria and hands the money and the signed copy over to the cashier. Students use their own mopeds or bikes to deliver the pizzas.

Stock control

Every Thursday morning, the stock manager performs a stock control. If new supplies are necessary, based on the current amount of all ingredients and average weekly consumption, he places an order via telephone or email to the Eat Fresh warehouse. Orders that are placed before lunchtime are delivered a following day. When the supply is delivered, the manager checks its completeness and signs the documents. In case the supply would not arrive by 3pm the following working day, the stock manager calls the warehouse to remind them of the order, which would, however, in this case be delivered the following working day.

New employee's admission

Because Eat Fresh is a chain, the manager when admitting new employee must follow the chain's policy. For a position "deliverer" may be employed only students, who are over 18 years old. They must have their own bike or moped. The HR manager after receiving the application form, CV, picture and a letter from school stating the applicant is a student, asses the application and decides if he will accept the applicant. If the applicant is accepted, the manger calls him and sets an appointment with him to fill and sign all necessary paperwork. For other positions, like cashier, or cleaner the procedure is the same, but the applicants do not need to be students.

For a position "cook" are the rules and procedure more complex. The applicant must be a certified cook, with at least one year experience. The HR manager receives all the documents, which are same as for other applicants, but in addition to that, the applicant must also include a copy of his certificate. The manager asses the application, and if he likes the applicant he invites him to an interview, where he makes a final decision. If he decides to offer the applicant a position, the applicant must undertake a medical examination, which is done by a special department in a local medical clinic. The manager books by himself in an online application an appointment at the clinic. He also sets a date for a final appointment, after expected results of medical checkup. The examination is paid by the applicant, and the payment must be done before the appointment. It can be paid either in cash in the clinic's building, or as a bank wire from his bank account, for which he needs to print a confirmation of the transaction, or by direct bank deposit, in which case he also needs to have a confirmation from the bank. After receiving the results of the medical check-up, the HR manager meets the applicant again to fill and sign all necessary paperwork. This final meeting was scheduled on the first meeting. If however on the morning of the appointment the HR manager still does not have the results from the medical clinic, he will call the clinic to find out when they would arrive, and according to that reschedule the final meeting with the applicant.

8.2 The BORM model

The BORM model consists of the Object Relationship Diagram and the Business Architecture Diagram. According to the BA, there are three main areas: Purchase, Stock, HR. For each, the ORD is included.

Purchase: Purchasing pizza consists in the BORM model of 4 processes: **Order placement** (8.3) and **Order preparation** (8.2), which are always completed, followed either by **Order take-away** (8.5) or **Order delivery** (8.4).

Stock: One process in the Stock - the Stock control in the ORD visible in figure 8.6.

HR: The process af accepting new employee is more complicated, because there is a different procedure when accepting applicants for different positions. In the ORD, instead of using conditions, this should be modeled as two process. The part which both would have in common, can be modeled in one process, with conditional split into sub-processes, as is visible in figure 8.7. In this case,

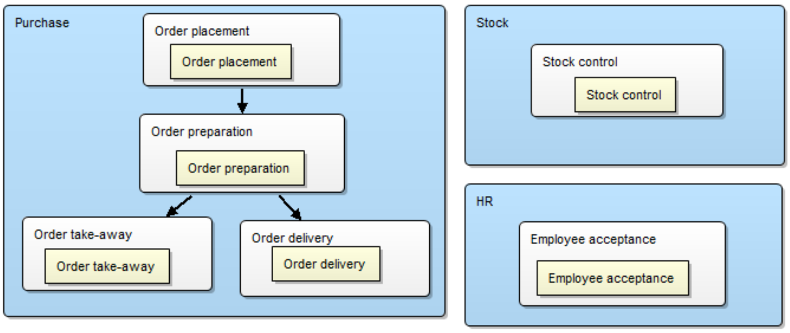


Figure 8.1: The Business Architecture diagram

the activities *assess application - cook* and *assess application - other* would be specified in greater detail.

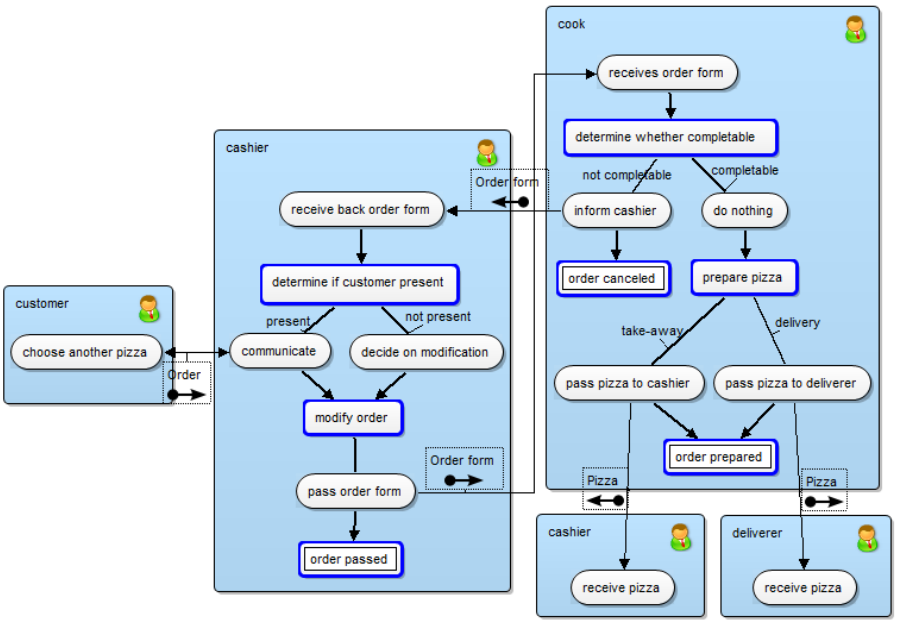


Figure 8.2: ORD: Order preparation

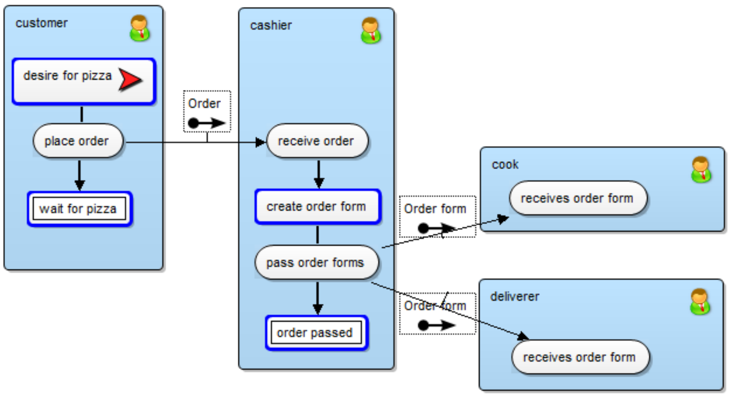


Figure 8.3: ORD: Order placement

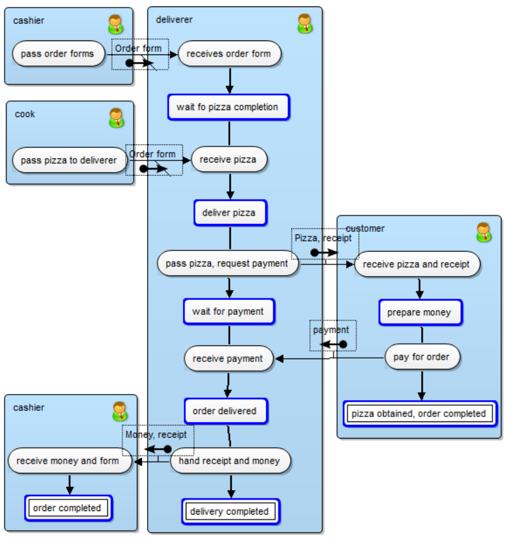


Figure 8.4: ORD: Order delivery

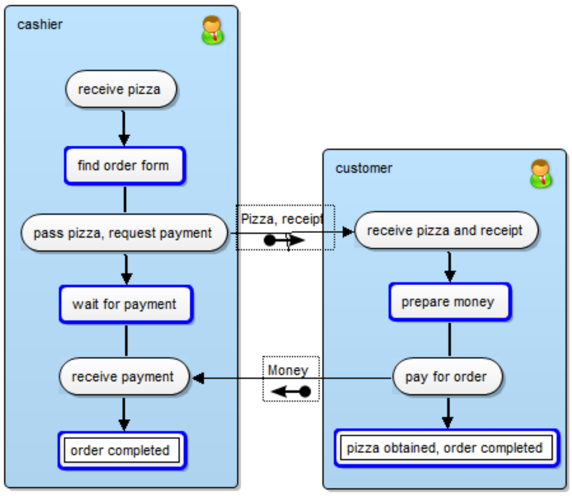


Figure 8.5: ORD: Order take away

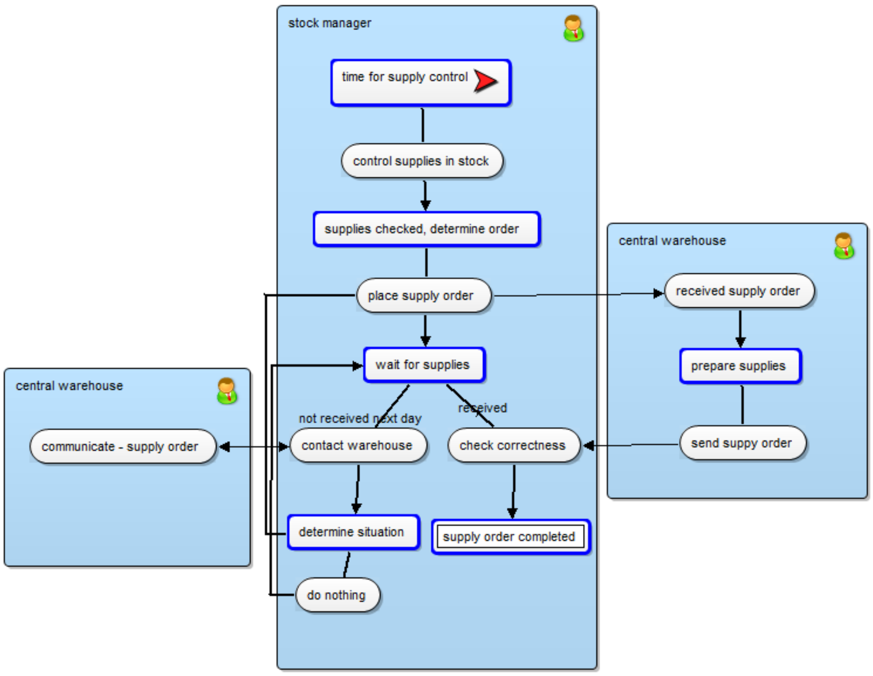


Figure 8.6: ORD: Stock control

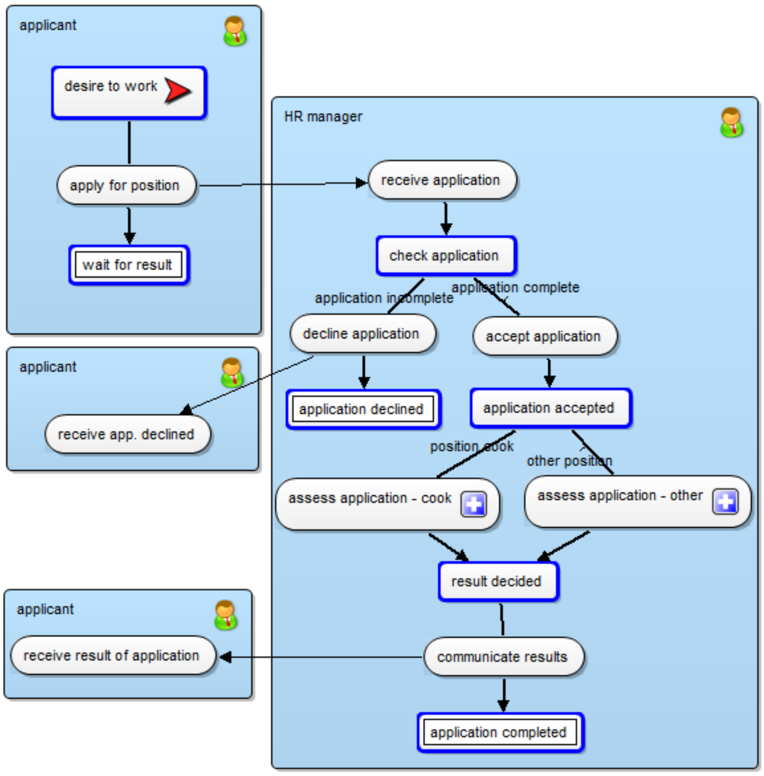


Figure 8.7: ORD: Employee acceptance

8.3 The BPMN model

The model in the BPMN consists of three diagrams (the BPD) - each for one identified process, which are displayed in following figures: 8.9 and 8.8.

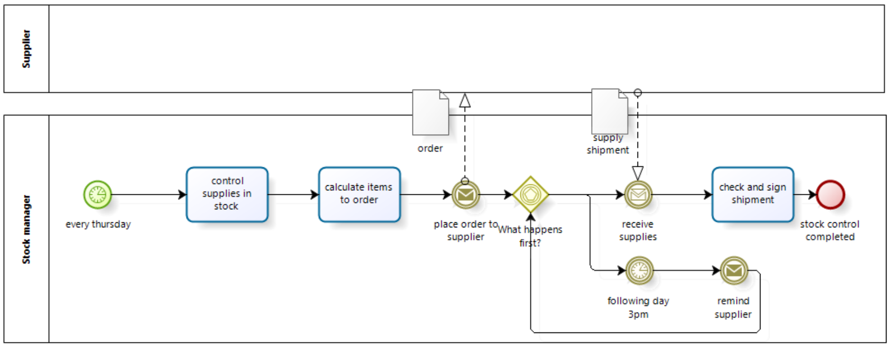


Figure 8.8: BPMN: Stock control

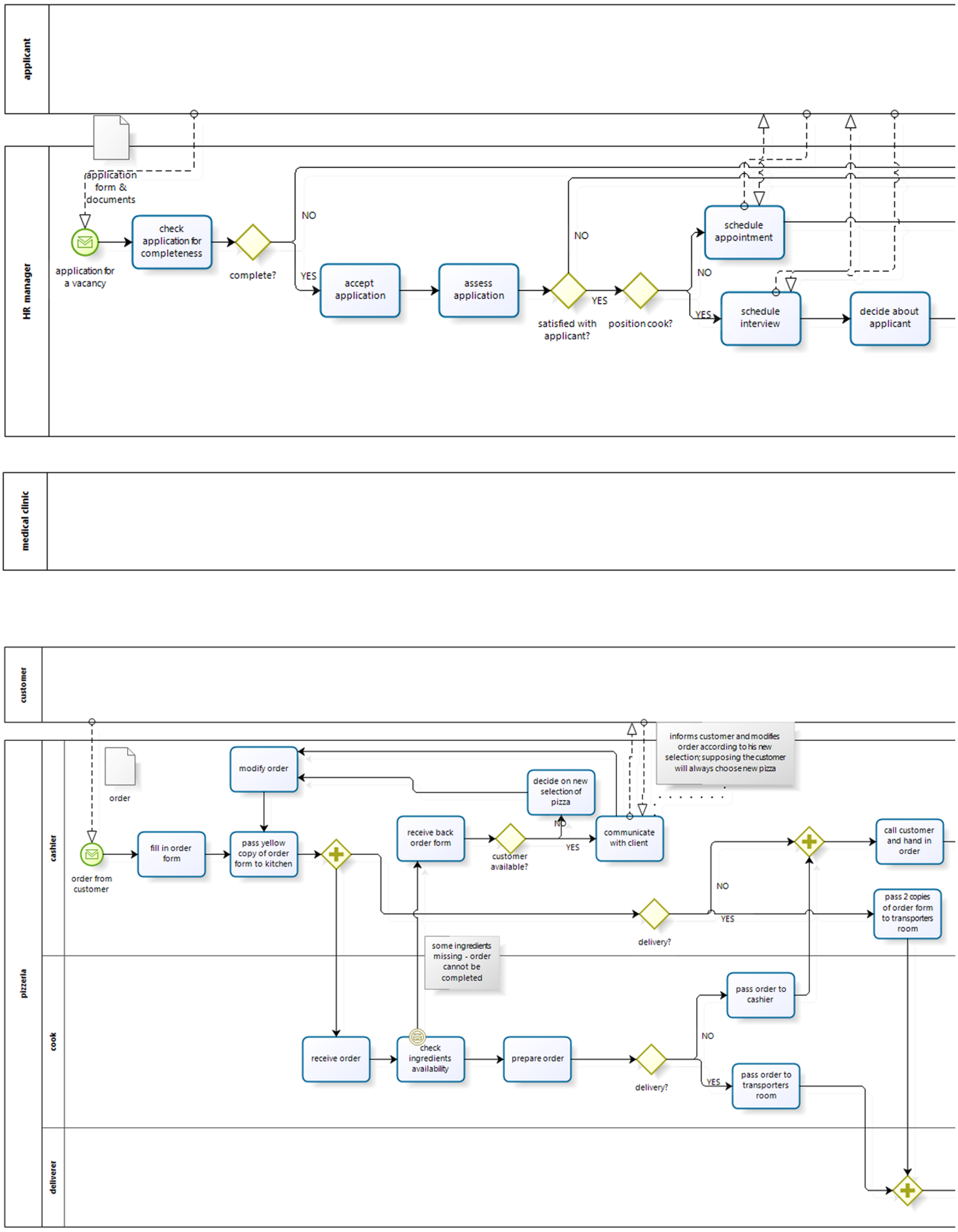
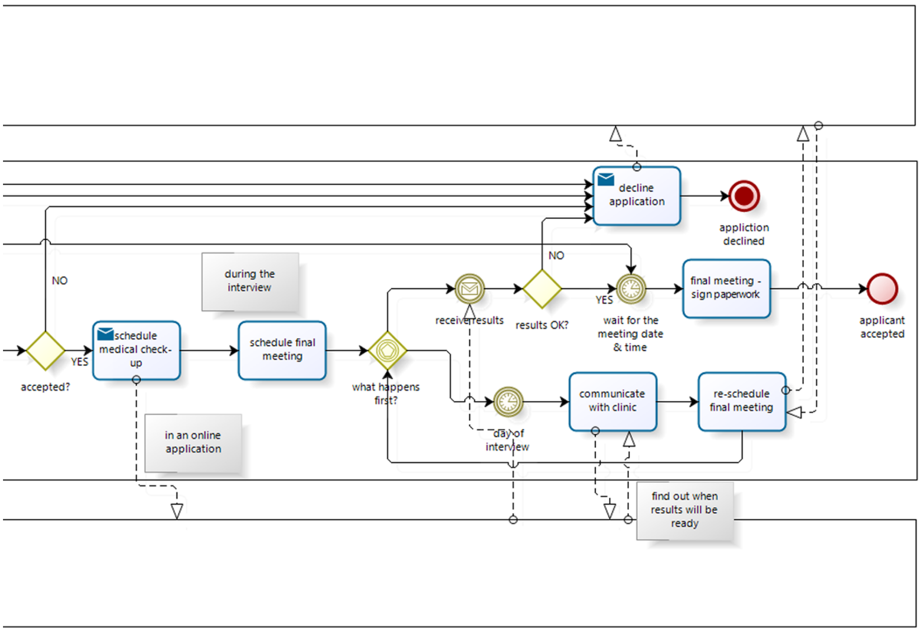
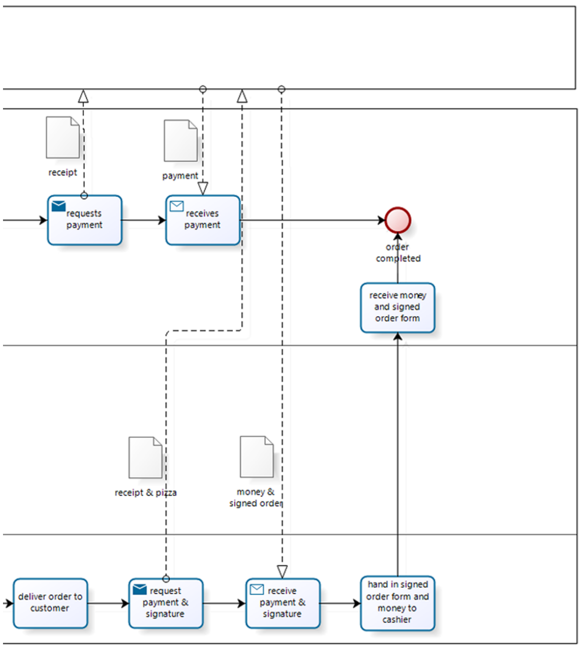


Figure 8.9: BPMN: Purchase completion; Employee acceptance


decline application
appliction declined
NO
during the interview
final meeting - sign paperwork
applicant accepted
receive results
results OK?
YES
wait for the meeting date & time
NO
accepted?
YES
schedule medical check-up
schedule final meeting
what happens first?
communicate with clinic
re-schedule final meeting
day of interview
in an online application
find out when results will be ready


receipt
payment
requests payment
receives payment
order completed
receive money and signed order form
receipt & pizza
money & signed order
deliver order to customer
request payment & signature
receive payment & signature
hand in signed order form and money to cashier

8.4 The DEMO model

The full DEMO model is created in correspondence with the guidelines presented in Chapter 6, section 6.4.3.

1. The Performa-Informa-Forma analysis

This step aims at identifying all ontological transactions. The best way to conduct the Performa-Informa-Forma analysis is to color in the original case description all ontological transactions red, all infological transactions green and all datalogical transactions blue.

2. The Coordination-Production analysis and Actor role analysis

The goal of this step is firstly to classify whether an act is a C-act or P-act and to identify all actor roles from the case. The results of this step are visible in following tables. The Performa-Informa-Forma analysis and the Coordination-Production analysis is also in details in a file on the attached CD.

Identified actor roles

There were in total 9 actor roles identified in the case example:

- **Cashier** – employee of pizzeria, handles completion of purchases
- **Cook** – prepares the purchases (pizzas)
- **Deliverer** – employee of pizzeria, delivers pizza to customer
- **Customer** – person who wants to order a pizza, requests a purchase, pays for a purchase
- **Supply manager** – performs stock control, orders new supplies
- **HR manager** – accepts new employees
- **Applicant** – person who applies for a position in a pizzeria
- **Medical clinic (doctor)** – performs medical check-up
- **Payer (Applicant)** – pays fee for the medical check-up (this will very probably be physically the same person as an applicant, but may not – as long as the fee is paid, the clinic does not care who paid it)

3. The Transaction pattern synthesis

This step aims at precisely formulating pairs transaction type – result type. It also takes all the identified C-acts 8.2 and matches them to one of the transaction pattern's steps. During this step, the Transaction Result Table (8.1) is produced.

Transaction type		**Result type**	
T01	Purchase completion	R01	Purchase P has been completed
T02	Purchase preparation	R02	Purchase P has been prepared
T03	Purchase delivery	R03	Purchase P has been delivered
T04	Purchase payment	R04	Purchase P has been paid
T05	Stock control	R05	The stock control for week W has been done
T06	Supply order completion	R06	The supply order S has been obtained.
T07	Applicant acceptance	R07	Applicant A has been accepted for employment
T08	Medical check-up performance	R08	Medical check-up M of applicant A has been performed
T09	Medical check-up payment	R09	Medical check-up M has been paid

Table 8.1: The Transaction Result Table

4. The Result structure analysis

The structure of results is determined. There are three processes in the pizzeria – purchase completion, stock control and application for employment. Stock control includes two transactions, which results are not dependent on each other. Figure 8.10 displays the result structure chart for purchase completion. To complete the purchase in pizzeria, the purchase has to be prepared, delivered and paid. To complete applicant acceptance, the medical check-up has to be completed, and to complete medical check-up, the payment must be done. This dependency is displayed in figure 8.11.

5. The Construction synthesis

The aim of this step is to identify all actor roles, and classify who is executor and who is initiator. The actor roles were identified in step 2, the table 8.3 summarizes for each of them and each transaction type who is initiator and who is executor.

In this table are the actor roles, not the actual people. For example the actor role completer would be performed by the cashier.

[Customer] walks in and (places) an order	T01 request
[cashier] (slides) the yellow one through the hatch	T02 request
[she] (hands) the blue copy into the transporter's room	T03 request
[Cook] puts had through the hatch and (notifies) the cashier	T02 decline
[cashier] (confers) with [him/her]	T02 request
[she] (changes) the order by herself	T02 request
[cook] (slides) the pizza(s)	T02 state
[cashier] (hands him) the pizza(s)	T01 state
[deliverer] (hands) in pizzas to the [customer]	T01 state
[stock manager] (places an order)	T05 request
[stock manager] checks its completeness and (signs)	T05 accept
[HR manager] after (receiving)	T07 request
[HR manager] (books)	T08 request
After (receiving) the results	T08 state

Table 8.2: Identified C-acts

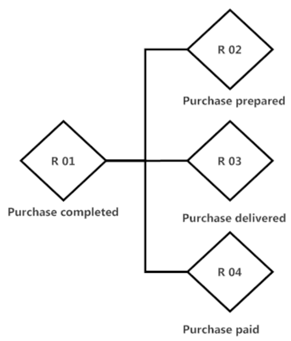


Figure 8.10: Result Structure Analysis: Purchase completion

6. The Organization synthesis

In this step a final choice of what is are internal and organizational transactions is made. Organizational transactions are those on the border of the organization's boundary – where the initiator or executor is not from pizzeria. Those fully

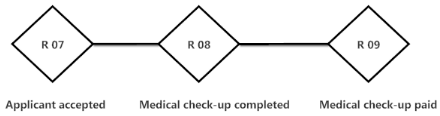


Figure 8.11: Result Structure Analysis: Employee acceptance

Transaction type		Initiator	Executor
T01	Purchase completion	Customer	Completer (Pizzeria)
T02	Purchase preparation	Completer (Pizzeria)	Cook
T03	Purchase delivery	Completer (Pizzeria)	Deliverer
T04	Purchase payment	Completer (Pizzeria)	Customer
T05	Stock control	Stock manager	Stock manager
T06	Supply order completion	Stock manager	Stock deliverer
T07	Applicant acceptance	Applicant	HR manager
T08	Medical check-up performance	HR manger	Doctor (Medical clinic)
T09	Medical check-up payment	Receptionist (Medical clinic)	Payer (Applicant)

Table 8.3: Construction synthesis: Initiators and Executors

performed outside are not captured, with one exception, which is the medical check-up fee payment. I have included this one in the TRT and will include it in following diagrams, because it is an important part of the application process. Table 8.4 states for each transaction type whether it is organizational, internal or external. Based on tables 8.3 and 8.1, the ATD (figure 8.12) can be constructed.

In the ATD are three actor roles the composite actor roles. The composite actor role means there may be multiple actor roles inside. For example Applicant is a composite actor role, which may consist of applicant – who initiates T07 Applicant acceptance, and payer, who executes T09 Medical check-up payment.

As is visible from the Actor Transaction Diagram, there are three separate processes in pizzeria:

1. Purchase completion

2. Stock control

3. Applicant acceptance

Transaction type		Transaction position
T01	Purchase completion	Organizational
T02	Purchase preparation	Internal
T03	Purchase delivery	Internal
T04	Purchase payment	Organizational
T05	Stock control	Internal
T06	Supply order completion	Organizational
T07	Applicant acceptance	Organizational
T08	Medical check-up performance	Organizational
T09	Medical check-up payment	External

Table 8.4: Organizational synthesis: Transaction type - position

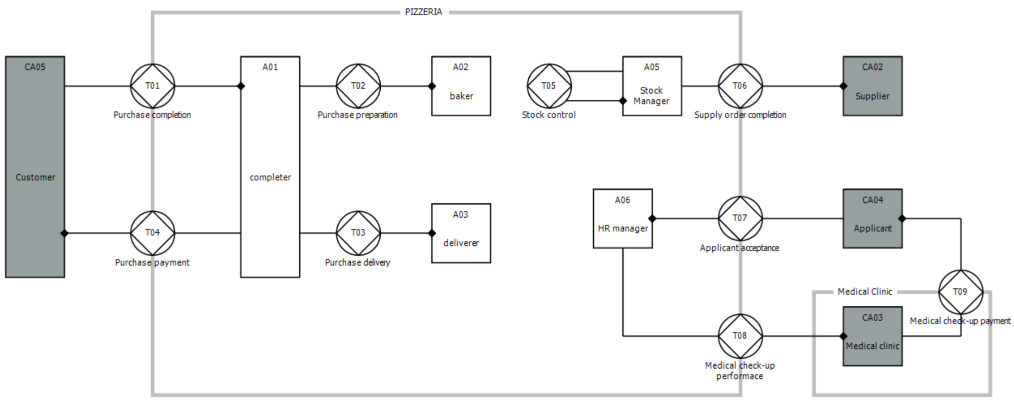


Figure 8.12: The Actor Transaction Diagram

7. Construction of PSD

The transactions within one process are interrelated, and the Process Structure Diagram reveals their relation. A transaction is either initiated within the process, or is a customer transaction or is a self initiated transaction. The transactions initiated within the process may be initiated on request, on promise, on state or on accept. There are two types of links in the PSD: the **causal links**, which links together the process steps, and the **conditional links**, sometimes also referred to as wait link. The conditional link defines when a process step of one transaction is waiting on completion of a process step of another transaction. The sequence and dependencies of process steps is determined by the result structure analysis, the waiting links based on the case description.

There are two types of diagrams that may be used. In the newer the transaction looks like a sausage. The advantage of this notation is that the PSD of a complex process would be relatively small and readeable. The original notation allows to display each process step separately. It is sometimes called the Transaction pattern diagram, and as the name suggests used mainly for displaying the full transaction patter. It may, however, be used for the PSD as well. This diagram is in my opinion easier to understand, even though for a process containing many transactions would be very large. Since the identified processes do not include more than 4 transactions, I include both diagrams.

1. Purchase completion process

- T01 is a customer transaction – is initiated from outside by a customer.
- Execution of T03 purchase delivery waits at acceptance of T02 purchase preparation. The delivery is requested and promised immediately when purchase completion is promised, but can be executed only after the purchase is prepared.
- Request of T04 purchase payment waits on acceptance of pizza (acceptance of T03 purchase delivery).
- T02 (purchase preparation), T03 (purchase delivery) and T04 (purchase payment) are executed sequentially as a part of T01 (purchase completion).
- Wait link *T02 acc – T03 ex* may be from accept to execution, because it is done within one organization, the deliverer can promise delivering the pizza even before it was completed, because he knows it will be completed.
- Wait link *T03 acc – T04 rq* is from accept to request, because we cannot request a customer to pay for the pizza that has not been delivered yet. Once the customer accepts the delivered purchase, he is requested to pay.

2. Stock control process

- T05 is a self-initiated transaction – is initiated on a periodic basis.
- Transaction T06 (Supply order completion) is optional.
- The Stock control (T05) is completed after the supply order is completed (T06), therefore T05 ex waits on T06 acc.

3. Applicant acceptance process

- T07 is a transaction initiated from outside – in this case by an applicant.
- This is an example of so-called deep nested transaction. T09 is enclosed within T08. T08 is enclosed within T07.
- Completion of T08 is dependent on completion of T09 – wait link from T09 acc to T08 ex.
- Completion of T07 is dependent on completion of T08 – wait link from T08 acc to T07 ex.

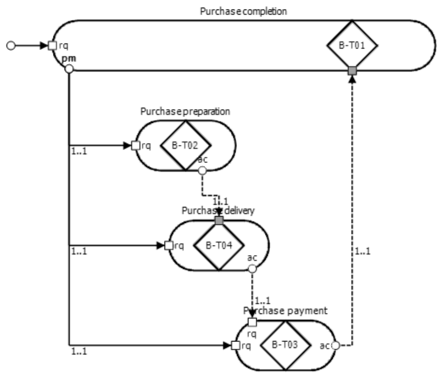


Figure 8.13: The PSD: Purchase completion

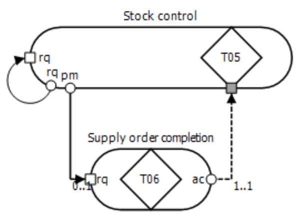


Figure 8.14: The PSD: Stock control

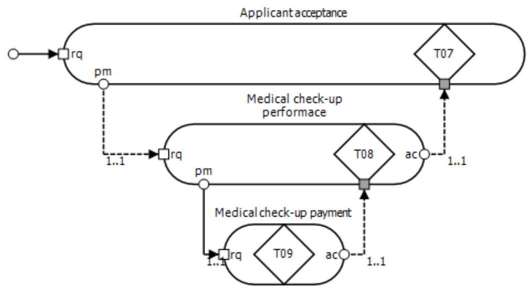


Figure 8.15: The PSD: Applicant acceptance

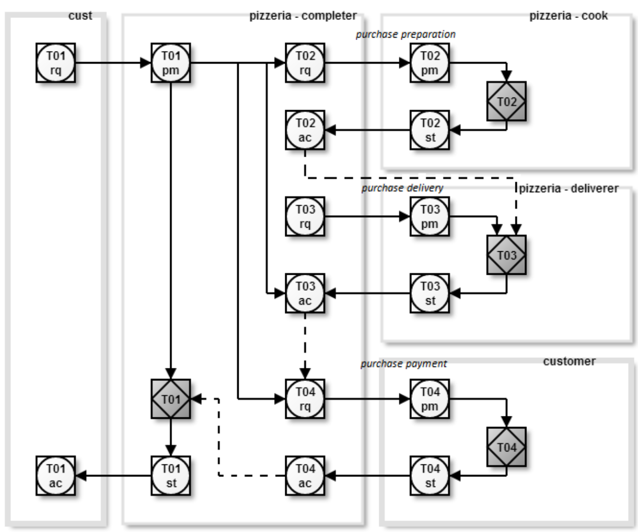


Figure 8.16: The detailed PSD (transaction steps): Purchase completion

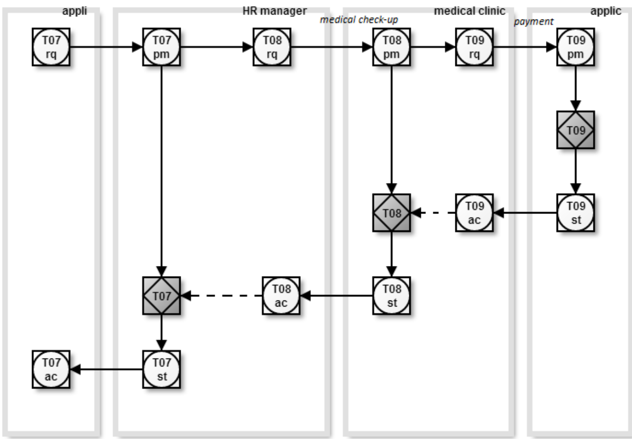


Figure 8.17: The detailed PSD (transaction steps): Applicant acceptance

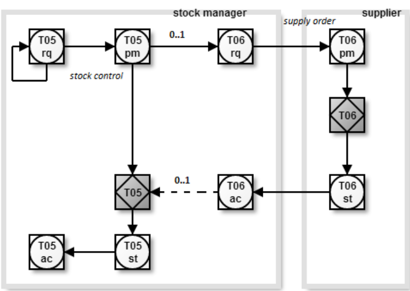


Figure 8.18: The detailed PSD (transaction steps): Stock control

8. Conditions, constraints and action rules identification

To conserve space, the Action rules are included on the atteached CD.

9. Construction of the OFD and OPL

There are following core categories: PERSON, PIZZA_KIND, PURCHASE, SUPPLY_ORDER, ITEM, VACANCY, APPLICATION. Other external objects like clinic are not mentioned.

Property type	Object class	Scale
delivery__address	PERSON	ADDRESS
pizza__price	PIZZA__KIND	EURO
total__price(*)	PURCHASE	EURO
age	PERSON	NUMBER

Table 8.5: The Object Property List

Figure 8.19: The OFD: Purchase completion

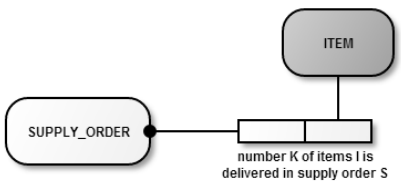


Figure 8.20: The OFD: Stock control

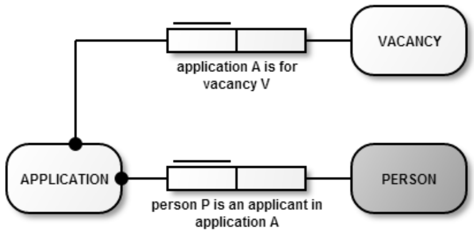


Figure 8.21: The OFD: Applicant acceptance

10. Construction of IUT

The IUT (table 8.6) specifies for each object class/fact type/result type in which steps of the PM it is used.

Object class, fact type, result type	Process steps
PURCHASE	T01/rq, T02/rq, T03/rq, T04/rq
CUSTOMER	T01/rq
C is the customer of P	T01/rq, T03/rq
PIZZA_KIND	T01/rq, T02/pm
total_price	T02/rq
delivery_address	T03/rq
SUPPLY_ORDER	T06/rq
ITEM	T06/rq
VACANCY	T07/rq
APPLICATION	T07/rq, T08 rq
application A is for vacancy V	T07/rq

Table 8.6: The Information Use Table

11. Identification of information flows

Final step is an identification of information flows and construction of the Actor Bank Diagram (figure 8.22), Bank Contents Table (table 8.7) and the Organization Construction Diagram (figure 8.23). The BCT summarizes what information is stored in which bank. The OCD is a combination of ABD and ATD.

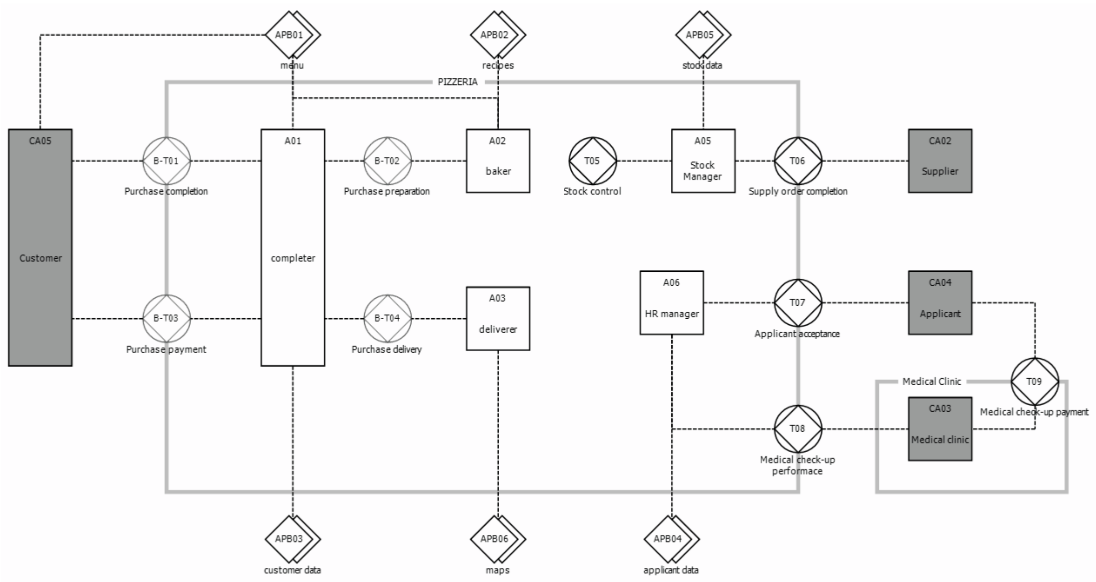


Figure 8.22: The Actor Bank Diagram

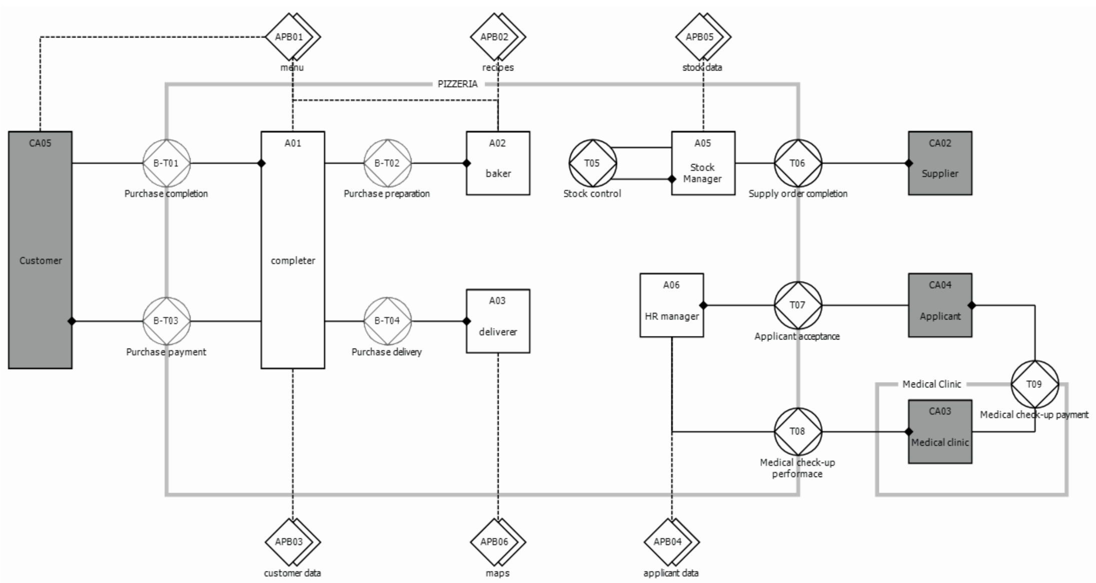


Figure 8.23: The Organization Construction Diagram

Object type, fact type or result type	**P-bank**
PURCHASE	APB03
person C is the customer of purchase P	
purchase P contains N pizzas of kind K	
purchase P has been started	
purchase P has been prepared	
purchase P has been paid	
purchase P has been delivered	
PERSON	
Delivery address	
PIZZA_KIND	APB01
recipes	APB02
maps	APB06
ITEM	APB05
STOCK ORDER	
stock control has been performed	
stock order S has been started	
VACANCY	APB04
person A is the applicant in application A	
application A is for vacancy V	
application A has been started	

Table 8.7: The Bank Contents Table

8.5 Petri net simulation model

Based on the case description and a method for translating the DEMO model into a Petri net simulation model (Chapter 7), a following Petri net models has been created, using the CPN Tools [28] and a high-level Petri net:

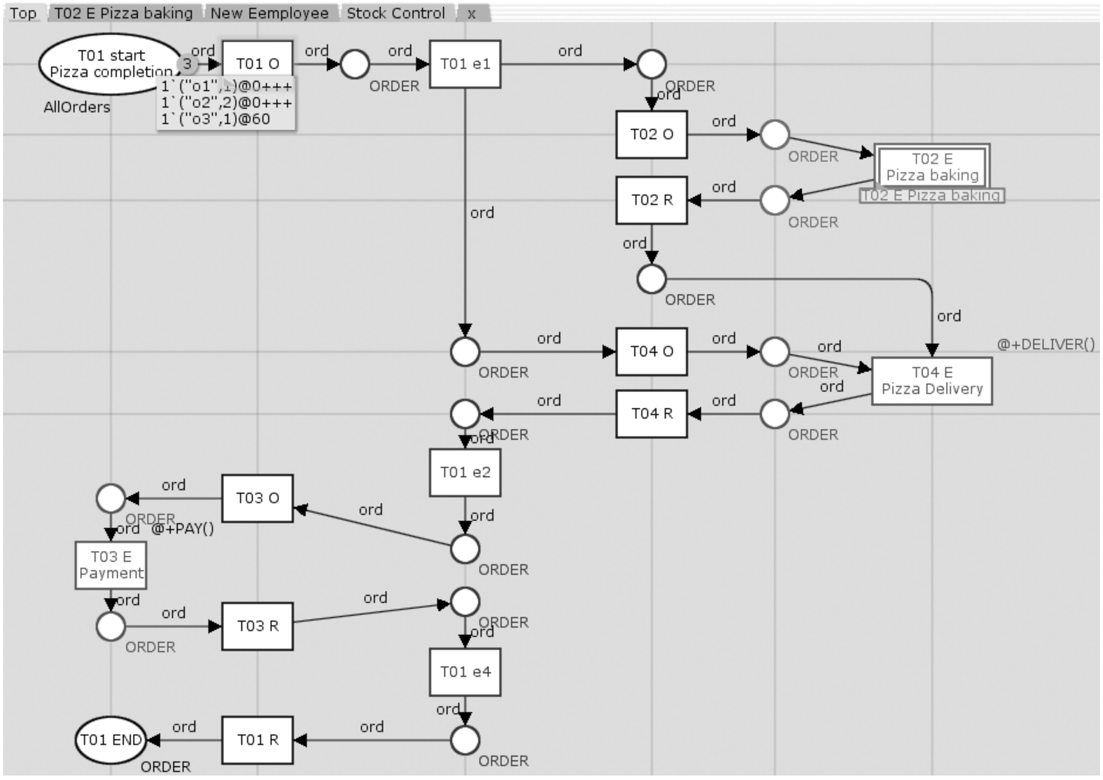


Figure 8.24: Petri net model: Purchase completion

The hierarchy in Petri net allows to specify some steps in detail. This was done in case of the transaction *Pizza baking*, and is visible in figure 8.27.

The performance analysis is one of the main reasons why simulation studies are conducted. A high level Petri net allows measuring time (on transition, waiting time etc.) due to its time extension. In the case example, the performance was measured for the first process, the order completion. Each transition was assigned time duration, which was calculated according to specified distribution function, and a number of resources.

For example in the order completion process, delivery was set to take between 300 and 600 seconds (discrete distribution) and payment between 30 and 180 seconds (discrete distribution). Pizza baking is modeled in a greater detail, which is visible in figure 8.27. Time and resources (cook or oven) are assigned to pizza

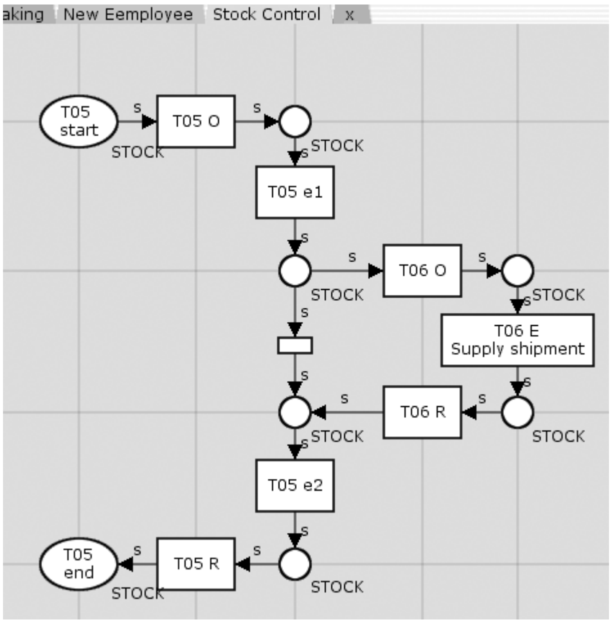


Figure 8.25: Petri net model: Stock control

preparation, baking and packing. The performance measurement was conducted on a case of 10 incoming pizza orders within 10 minutes. Each sample was measured twice, once using discrete distribution of case arrival and once using regular (one case per minute) incoming rate.

The final values are average of the two measurements. The details of measurements is included on the attached CD. Based on the results, the shortest average time of order completion, including delivery, is 22 minutes with 3 cooks and ovens that fit 6 pizzas. However, employing only 2 cooks and having oven that fits 5 pizzas increases the average completion time only to 24.5 minutes.

The measurement was included here just to demonstrate what is possible to do with the high-level Petri net, not to provide some conclusions about the particular case.

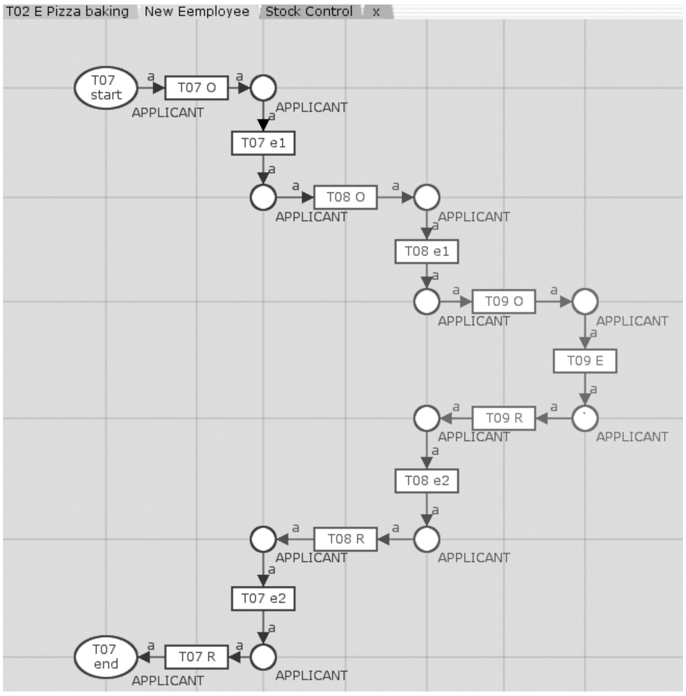


Figure 8.26: Petri net model: Applicant acceptance

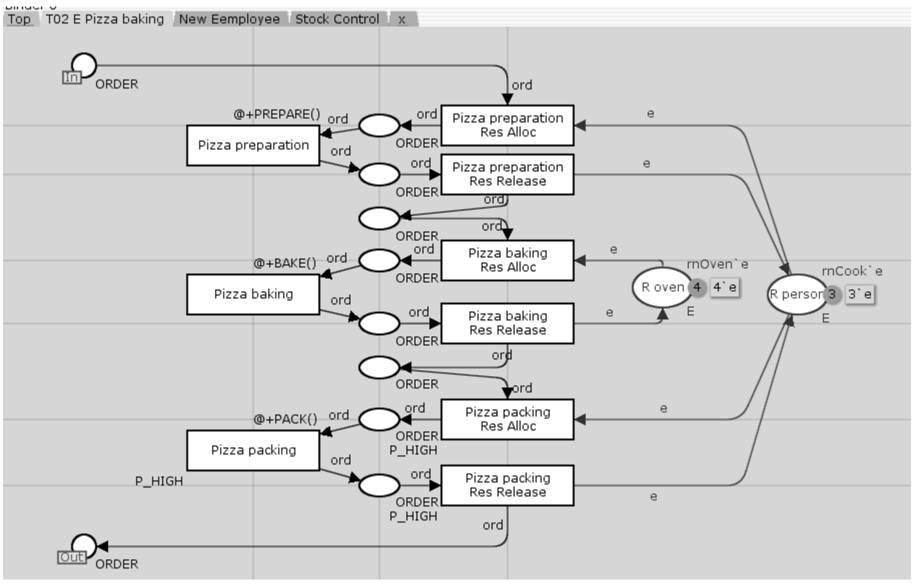


Figure 8.27: Petri net model: Pizza baking

Chapter 9

Comparison

The comparison of the BORM methodology, the BPMN and the DEMO methodology may be done from few different perspectives. Because each has been developed to serve a different purpose, it is not as straightforward as it would be if comparing two similar ones. To be clear with the used terminology, BORM and DEMO are methodologies. BPMN is a standard, but in the Chapter 5 the Method and Style for creating a *"good BPMN"* was described. Part of that arises from the definition of the standard, part is a best practice introduced by Silver [91]. As this is taken into account, the BPMN may be in this chapter referred to as a method (or methodology), but it is important to keep in mind that officially it is just a standard.

Firstly, the summary of main characteristics of the BORM methodology, the BPMN and the DEMO methodology is presented in table 9.1, which is based on previous Chapters – 4, 5, 6. Then, the methodologies are compared theoretically, based on business process modeling perspectives, purpose and benefits, presented in Chapter 2. The main focus is on comparison based on purpose and application of Business Process Modeling. The subsequent practical comparison presents a SWOT analysis for each methodology, not for any common purpose, but each for its intended usage. Lastly, the methodologies are evaluated based on defined criteria.

9.1 Summary of main characteristics

	BORM	BPMN	DEMO
Description	Method for organizational modeling of business processes prior to IS development. Covers both business engineering and software engineering and in 6 steps describes development life cycle from business process identification to information system implementation.	BPMN is a standard that defines the notation for business process models. It is an expressive language, able to describe nuances in process behavior as well as the technical details that control process execution in one diagram – the Business Process Diagram (BPD).	Method for modeling an organization and its processes. It reveals both construction and operation of an organization while abstracting from the implementation. The complete model consists of 4 aspect models.
Purpose & Motivation	A major problem in software engineering arises in the initial stages of the entire IS development process, namely in aligning the system with the actual business needs. The goal of the BORM methodology is to smoothly go from business analysis and simulation to subsequent UML software development.	The main goal of BPMN is to provide a notation that is understandable for all business users as well as technical analysts. As it is standardized, it is supported by different vendors, not dependent on just one. In BPMN 2.0 the focus also lies on providing an official XML interchange format for process models, which also makes the process models executable in a process engine.	As modern enterprises are growing in complexity and involve human interaction, there is no method that would capture the enterprise in a complete yet easily understandable way for the purpose of its redesign. The goal of DEMO is to reveal both the construction and the operation of an enterprise, on an ontological level. It would be useful for understanding its operation and for implementing changes.
Fundamentals	1) Object oriented approach – process models are composed from business objects, that contain both structural and behavioral description. 2) Automata theory – every object is viewed at as a state machine with states and transitions dependent on the behavior of other objects. The BORM methodology contains in the first stage only two diagrams (ORD and BA) which cover states, transitions and operations for all subjects playing role in a business process.	It is based on flowcharting technique. BPMN has no official methodology, it specifies 2 things – the modeling notation and a formal semantics of the elements' definitions and their inter-relationship.	Combination of communicational and functional perspective, based on the PSI theory. The main 3 features are: (1) system of actors (initiator and executor), production and coordination acts; (2) extraction of the essence of an organization and business processes from their realization; (3) transaction pattern, which describes sequence of acts between actors and ensures all C-acts, even those performed tacitly, are detected.
Application	1) IS development (identifying requirements for software engineering) 2) Business Process Improvement (AS-IS and TO-BE process models)	BPMN is used for creating standardized process models. Those can be used either for documentation purposes, AS-IS/TO-BE process modeling, or further for process implementation.	1) Enterprise and organizational study – enterprise and business processes transformation and (re)design 2) Implementation of an organization – aligning enterprise architecture 3) Software engineering – starting point for requirements analysis (IS development)
Advantages	1) Covers the whole IS development life cycle, with focus on covering the gap between business engineering and software engineering 2) The first stage includes two diagrams (BA and ORD), which are: a) simple and understandable to business users; b) cover information about process and objects from 3 different dimensions (data, history, behavior); c) the ORD can be directly simulated	The only diagram – BPD can be used for both business users and developers. Its main advantages: 1) Understandability for business users 2) Notation is a standard supported by many vendors 3) It contains technical details for implementation	1) Ability to master complexity of current enterprises, by focusing only on the ontological level 2) Strong theoretical background, making the final model coherent, comprehensive, consistent, concise and essential 3) It gives a holistic and implementation-independent view of an enterprise

Table 9.1: Summary of main characteristics of BORM, BPMN and DEMO

9.2 Theoretical comparison

In Chapter 2, an overview of business process modeling perspectives and application of business process modeling was presented. Each of the methodologies can be positioned into one of the perspectives, which is displayed in table 9.2. Table 2.6 summarized the theoretical application of each perspective in relation to identified application of constructed process model. By classifying the methodologies into the perspectives, the theoretical application of each methodology for each purpose of process modeling is obtained - table 9.3.

	Perspective	**Shortcut**
BORM	Combination of **Object Oriented** and **Behavioral & Functional**	**OO and B&F**
BPMN	**Behavioral & Functional**	**B&F**
DEMO	Combination of **Communicational** and **Functional**	**Com. and Func.**

Table 9.2: Classification into perspectives

The application gained as a result of this theoretical comparison based on the perspectives of process modeling is very general. **For the first sight**, the BPMN model is most suitable for capturing and analyzing, and together with the DEMO model also for presenting. However if we would make the distinction with a greater detail – by individual application, not just by purpose, the results would look differently. For example the BPMN model is definitely more useful for presenting business processes, than the DEMO model, but based on the perspectives the applicability seems the same.

The detailed comparison takes into account not only the applicability of each perspective for a certain purpose, but also the description of the methodologies (summarized in table 9.1). Prior to that, description of each item (application area) is provided, in some cases with a reference to a part of the case example presented in Chapter 8. After the description of each item, in the table 9.4 is summarized the suitability of the BORM methodology, the BPMN and the DEMO methodology for each application. They are ordered according to the applicability, so 1st means the highest applicability and 3rd the lowest. In case there is no applicability for a given application, the methodology is not mentioned at all.

<table>
<tr><th>Purpose of process modeling</th><th>Application of constructed process model</th><th>Model properties</th><th>Applicable perspectives (some applicability)</th><th>BORM, BPMN or DEMO?</th></tr>
<tr><td rowspan="3">Capturing</td><td>Process oriented Information system development</td><td rowspan="4">legibility, understandability, unambiguity</td><td rowspan="2">Functional, Behavioral & Functional</td><td rowspan="4">1. BPMN (B&F),
2. BORM (partly B&F) and DEMO (partly Func.)</td></tr>
<tr><td>Input into classical software development project</td></tr>
<tr><td>Requirements engineering</td><td rowspan="2">(Actor-Role, Topological, Rule-Goal, Communicational, Topological, Object-Oriented)</td></tr>
<tr><td>capturing/analyzing</td><td>Process verification</td></tr>
<tr><td rowspan="3">Analyzing</td><td>Process analysis - decision making about the process</td><td rowspan="5">presence of both dynamic and functional aspects</td><td rowspan="3">Behavioral, Behavioral & Functional, Functional</td><td rowspan="5">1. BPMN (B&F),
2. BORM (combination OO and B&F),
3. DEMO (partly Func.)</td></tr>
<tr><td>Process redesign / improvement / Change management</td></tr>
<tr><td>Process simulation</td></tr>
<tr><td rowspan="2">analyzing/presenting</td><td>Knowledge management (reporting, knowledge sharing)</td><td rowspan="2">(Rule/Goal, Object-Oriented, Actor-Role)</td></tr>
<tr><td>Alignment with organizational goals and strategic perspectives</td></tr>
<tr><td rowspan="3">Presenting</td><td>Process documentation, understanding and learning about processes</td><td rowspan="3">understandability also for process owners - diagramatic notation</td><td rowspan="2">Functional, Behavioral & Functional, Actor-role, Communicational</td><td rowspan="3">1. BPMN (B&F) and DEMO (combination Com. and Func.),
2. BORM (B&F)</td></tr>
<tr><td>Understanding the communication flow between entities in organization</td></tr>
<tr><td>Process validation</td><td>(Structural, Topological)</td></tr>
</table>

Table 9.3: Application of BORM, BPMN and DEMO based on perspectives

9.2.1 Detailed comparison by application in practise

Process oriented Information system development

The BPMN includes all the technical details, so the modeled process can be directly implemented in a tool designated for process execution. *For example in Stock-control process 8.8, it specifies what happens if the supply order is not delivered following day by 3pm, and that the stock control is performed every Thursday.*

Input into classical software development project

The ORD in the BORM model captures both the communication and process flow, making the roles and responsibilities clear. Similarly does the ATD in the DEMO model, where only the ontological transactions are visible. For these two, it is easy to map the model into a Use Case model for further software development. *For example in the ORD in Order preparation 8.2, it is clearly visible, when the information, order form or pizza is passed and who is responsible for which step.*

Requirements engineering

Requirements engineering deals with specifying the general requirements on the system. The BORM and DEMO models capture the initiator and executor, making the roles and responsibilities clear, so it is easy to specify requirements on each particular object. *This is visible in the 8.12 (DEMO model) and in the ORD (BORM model). It is important to keep in mind that each of the methodology model processes on different level, the BORM methodology on operational level and the DEMO methodology on the strategic, which would influence the obtained requirements on objects (actor roles).*

Process verification

Process verification deals with building the model right, namely capturing all the details right. That can be confirmed by simulation or syntax check, which is often up to the software tool. The methodology should include rules for building consistent models, which can be used to check the model. *Elementary rule in the ORD is that states and activities should alternate and starting and finishing states should be marked properly. In the ATD each transaction should have exactly one initiator and executor, and each actor role may be executor to only one transaction. In the BPMN, most constrains concern the process flow – for example message cannot be send within one pool etc.* **The verification comes down to the tool and is equally important in case of all three methodologies.**

Process analysis - decision making about the process

Decision making regards process design rather than operation of the process. The BORM and DEMO models are useful because they capture the process flow, communication flow, actor roles and interaction between them. The BPMN finds greater application in operational performance analysis.

Process redesign / Process Improvement / Change management

All methodologies are useful, each in a different way. The DEMO model could be used for process redesign on the strategic level, like decisions of outsourcing, mergers etc., because as is visible from the case example 8.12, only 9 ontological transactions were identified. The BORM and BPMN models have applicability for process improvement on the operational level, including the performance analysis, as the process flow is more detailed.

Process simulation

The DEMO model may not be directly simulated, therefore has no application for simulation. The ORD (BORM) and BPD (BPMN) have the formal semantics and syntax for simulation. They both can be used for performance analysis as well as to visualize the process, in order to validate the process with process users and analysts.

Knowledge management (reporting, knowledge sharing)

The knowledge sharing concerns the presenting purpose of process modeling, namely process documentation. Depending on the desired aspect, the BORM model may be used to document the process flow and the communication, the BPMN model may be used to document the operational details of the process. **For reporting, all methodologies are useful, depending on the content of the report** – the DEMO and BORM models for actor roles and communication, each on different level, and the BPMN model for the operational details and performance.

Alignment with organizational goals and strategic perspectives

The BORM and BPMN methodologies capture processes on the operational level. Because the DEMO methodology abstracts from the implementation, it is the one that could be best used on the strategic level, where questions of sourcing, mergers or acquisitions are dealt with.

Process documentation, understanding and learning about processes

The processes should be readable for users, which is rather the case of the BORM and BPMN models. However to learn about the processes on the organizational (ontological) level, it would be only the DEMO methodology, that could handle the complexity.

Understanding the communication flow between entities in the organization

The BORM model displays communication and information flow between the actor roles. It is one of the main focus of the methodology and it fulfils it right. The DEMO model displays the communication on the ontological level, and each transaction in the DEMO is set of four communicational acts. They both clearly display who interact with who, but the BORM model also reveals what information is being transferred, which in the DEMO done on the I-level. The BPMN displays communication only with external parties, so for example passing order form from cashier to cook has to be modeled as a process flow, not information flow, unless the cook and cashier would be modeled as a separate entities, each in a separate pool.

Process validation

Validation deals with building the right model – the model has to be an accurate representation of the reality. The processes should be validated for all purposes, and it is equally important for all three methodologies. As the BORM and BPMN models are more understandable for process owners, the validation is easier. In the DEMO, it is often done only by the analysts. A simulation often helps with processes validation.

	Applicability		
Application of constructed process model	**1st (highest applicability)**	**2nd**	**3rd (lowest applicability)**
Process oriented Information system development	BPMN	BORM	DEMO
Input into classical software development project	BORM	DEMO	BPMN
Requirements engineering	BORM and DEMO		BPMN
Process verification	BORM and BPMN		DEMO
Process analysis - decision making about the process	BORM and DEMO		BPMN
Process redesign / improvement / Change management	BORM, BPMN and DEMO		
Process simulation	BORM and BPMN		
Knowledge management (reporting, knowledge sharing)	BORM and BPMN		DEMO
Alignment with organizational goals and strategic perspectives	DEMO		
Process documentation, understanding and learning about processes	BPMN	BORM	DEMO
Understanding the communication flow between entities in organization	BORM	DEMO	BPMN
Process validation	BPMN and BORM		DEMO

Table 9.4: Detailed comparison of BORM, BPMN and DEMO

Each of the methodologies has some application in each identified process modeling purpose. To be able to compare the extent of usage within each purpose, based on the theoretical comparison based on perspectives (table 9.3) and detailed comparison (table 9.4), the methodologies were evaluated in a following way: *the first methodology by 3 point, second by 2 points and third by 1 point; for no application 0 points;* the points are summarized and averaged over each of the purpose.

When measuring applicability of each methodology within each purpose, it is interesting to see, how the detailed comparison (table 9.4) is different to the results the theoretical comparison (table 9.3) – the one based on perspectives. The results of both are visible in table 9.5. The detailed comparison is considered more accurate, because it takes into account all items listed within each purpose and is based not only on the perspectives, but also on the summary of each methodology, so it will be the one used further.

	theoretical comparison	detailed comparison
capturing	1. BPMN 2. BORM & DEMO	1. BORM 2. BPMN 3. DEMO
analyzing	1. BPMN 2. BORM & DEMO	1. BORM & DEMO 2. BPMN
presenting	1. BPMN & DEMO 2. BORM	1. BPMN 2. BORM & DEMO

Table 9.5: Theoretical vs detailed comparison

9.2.2 Comparison by purpose

For **capturing** business processes, which has application mainly in software development and requirements specification, has the overall highest applicability the BORM methodology. While the BORM and DEMO methodologies are useful for software development and requirements specification, the BPMN model provides technical details for implementing process oriented IS. **Models aiming on capturing business processes should be legible, understandable and unambiguous.** They are rarely used for simulation, yet the simulation might find some use here also – to visualize the process flow, in order to validate the process with process owners. Validation is for software development a crucial step.

For **analyzing** business processes, which includes simulation, decision making about the process and knowledge management, have the highest applicability the BORM and DEMO methodologies. The BORM methodology because its main model (the ORD) may be directly simulated and analyzed and the DEMO methodology because it captures the essence of the organization, which makes a good starting point for process redesign or improvement. The BPMN plays a role in operational processes measurement, analysis and optimization. **Models focused on analyzing business processes should include both dynamic and functional aspects.** It is important to realize what will be the purpose of the analysis, in regards to performance indicators, so that all necessary information is included in the model.

Presenting business processes includes process documentation and understanding the communication between entities. The BPMN has the highest applicability in presenting and documenting the process, as the notation is very detailed. The BORM and DEMO methodologies would be used rather for displaying the communication between entities, and assigning actor roles to the tasks. **The main requirement for the models used for presenting, is understandability for process owners.**

9.2.3 Comparison by benefits

The second approach to the comparison is by the categories of Business Process Modeling benefits. For an organization choosing a methodology would this comparison be more valuable, than the one based on purpose. It takes the categories of Business Process Modeling benefits and the application of Business Process Modeling, presented in figure 2.4. Based on the applicability of each methodology for each specific application (table 9.4), the methodologies are ordered by applicability for each category of business process modeling benefits, as visible in figure 9.1.

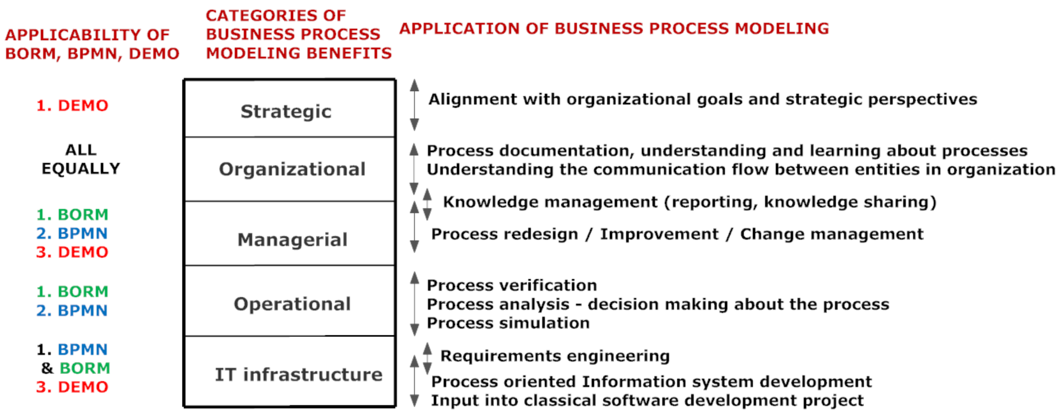


Figure 9.1: Applicability of BORM, BPMN and DEMO in relation to categories of BPMo benefits

IT Infrastructure includes benefits related to the IT support of business agility, reduction of IT costs and implementation time. **All three have application in this category, each in different way.** The BPMN for process execution, or so-called model-driven execution, while the BORM and DEMO methodologies rather for requirements specification and IS development.

Operational level covers benefits relating to reduction of process costs and execution times, increase of process productivity and quality and improvement in customer services. From this definition it is clear that we are talking about operational benefits and operational processes. **Both the BPMN and BORM methodologies, that model processes on the operational level, are applicable.**

Managerial level involves benefits provided to management in terms of improved decision making and planning. **All methodologies would be useful, each can be applied on a different level.** Because the ORD (BORM) and BPD (BPMN) can be simulated, they would be of a higher usage.

Organizational level includes benefits of strategy execution, learning, cohesion, and increased focus. Those involve understanding and documenting processes, as well as communication between entities. **All three methodologies could be applied, however each in a different way.** The BPMN and BORM methodology would be of a biggest use for process presentation and documentation, due to the understandable notations. The BORM and DEMO methodologies include the communication aspects.

Strategic level benefits focus on strategic activities such as long-range planning, mergers & acquisitions, product planning, customer retention. In this area, **the DEMO methodology is a number one,** as it models the whole organization, both its operation and construction.

9.3 Practical comparison

Choice of the Business Process Modeling methodology would mainly be done based on the expected benefits and intended purpose. None of the methodologies is perfect in all aspects, so after making the choice, or to confirm the choice, the organization would also consider the weaknesses or threats of the methodology. For analyzing those is often used the **SWOT analysis**.

It seems clear from a previous description of the methodologies and comparison that **the DEMO methodology is very different and the BORM methodology and the BPMN are close in a lot of aspects**. They both model processes on the operational level and are designated for both "business people" (process owners, users) and "technical people" (process analysts, software engineers). If choosing a methodology for presenting business processes, when deciding between the BORM methodology and the BPMN, the decision may be influenced by the level of detail one wants to capture. **The ORD (BORM) includes only simple elements, so the model is very readable, but the BPD (BPMN) allows to capture all operational details.** The comparison of modeling elements included in the BPMN and the BORM model is considered interesting, because it may influence the decision between the methodologies.

9.3.1 Modeling elements in the BORM methodology and in the BPMN

The modeling elements are summarized without further details in table 9.6. The goal of the comparison is not to explain each element in detail - that can be found in the specification, but to briefly show what are the possibilities. The notation used in the BORM methodology and the BPMN in Appendix C. It has been mentioned many times, that the BORM methodology has the goal to be very understandable, so it captures only the basis of the process and detailed semantics is expressed using written comments. On the other hand, the BPMN captures all details, up to the smallest nuances, meaning the notation is more detailed, which may be observed for example on the wide variety of event and gateway types.

	BORM	BPMN
Elements in the model	**Participant** – who performs the role; is initiated by activity or initial state **Activity** – what is done in the role – action or communication **State** – when something happens, may be active (participant in doing something) or passive (participant is waiting for something); states can be **initial, end** and inner	**Activity** – unit of work performed in the process (sub-process is compound activity) **Gateway** - controls the process flow, splitting options (exclusive, parallel etc.) **Events** – can be used as start (defines how the process can start) end (how the process can end), intermediate (triggers attached during the process flow); event types are: none, message, timer, error, escalation, cancel, compensation, conditional, link, signal, terminate, multiple, parallel multiple **Pool and Lane** – pool represents a container for a whole process, may be divided into lanes to represent actor roles
Connection of elements	**Communication** flow – connects two activities, can include data flow (data/physical objects) **Transition** between states – links between states (always state-activity-state); the process flow routing allows choice of two activities after state and parallel split, parallel join is possible only for same number of steps in each branch	**Sequence flow** – order of elements, a transition from an element to another may have attached data object or data store; the flow is routed based on gateways and events **Message flow** – represents communication between process and an external entity

Table 9.6: Elements in the model: BORM and BPMN

9.3.2 SWOT analysis

The SWOT analysis summarizes **Strengths, Weaknesses, Opportunities** and **Threads**. By definition, **Strengths and Weaknesses are internal factors**, **Opportunities and Threats are external factors**, over which the organization has no control. **Strengths and Opportunities are positive or helpful aspects**, **Weaknesses and Threats negative or harmful aspects** [62], which is visible in figure 9.2. **Strengths and Threads** are the two items primarily aspects that should be taken into account, because Strengths summarize why the particular methodology was chosen and Threats reveal the risky areas.

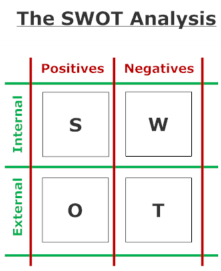


Figure 9.2: The SWOT analysis

The BORM methodology, the BPMN and the DEMO methodology, can be used for a different purpose, so the SWOT analysis, that would analyze the strengths and weaknesses for one in contrast with another, would not reveals as much new information, because what would in case of one methodology be a strengths and weakness, could in case of other be the other way round.

The first step in creating an accurate and useful SWOT analysis is setting the purpose of process modeling project, based on which the SWOT should be constructed. For each methodology, the purpose for which the SWOT is created, is described bellow. The items of the SWOT analysis can be described as:

- ***Strengths:*** characteristics of the methodology, that makes it applicable for the intended purpose of usage

- ***Weaknesses:*** characteristics that place the methodology in a disadvantage relative to potential another methodology, that would cover the mentioned aspects

- ***Opportunities:*** external factors that would have a positive impact on the methodology; including aspects, that may not be influenced by the organization using the methodology, but may be influenced by the authors of the methodology

- ***Threats:*** external elements that could have a negative impact on the methodology and therefore the organization using it

The SWOT analysis is interesting to consider when already a methodology is chosen, or in a final step of the choice. Similarly, the comparison of elements would be useful only in particular cases, when deciding on the operational level. Both are rather additional points of view on the comparison, and are not used furthermore in this thesis.

The BORM methodology

The typical application of the BORM methodology is capturing the business processes, as a first step prior to IS development. For this usage, the strengths, weaknesses, opportunities and threats presented in figure 9.3 were identified.

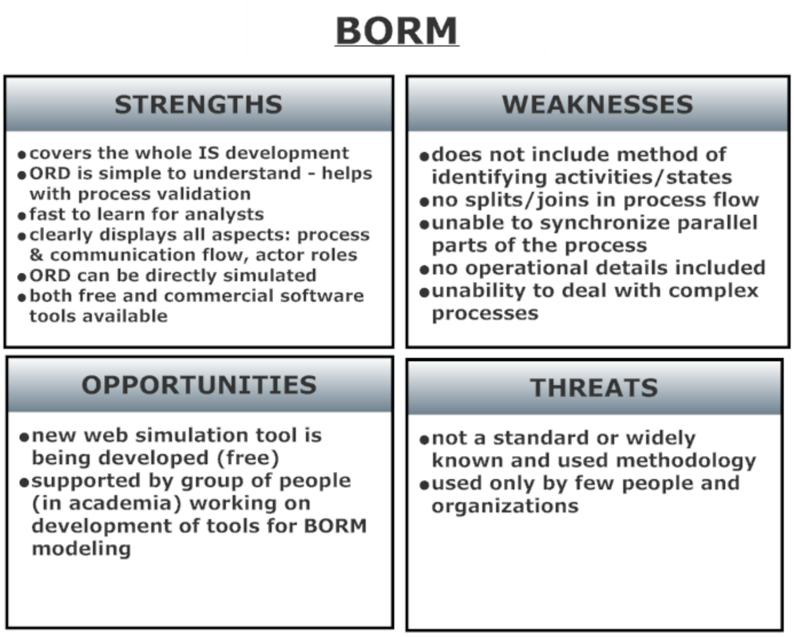


Figure 9.3: The SWOT analysis: BORM methodology

The BPMN

The BPMN is used mainly for documenting business processes and development of process oriented Information systems, which was selected for the analysis of strengths, weaknesses, opportunities and threats, displayed in figure 9.4.

The DEMO methodology

The DEMO methodology would most typically be used for construction of the organization, on the ontological level. The created model can then be used as an input into strategic redesign project. The strengths, weaknesses, opportunities and threats identified are summarized in figure 9.5.

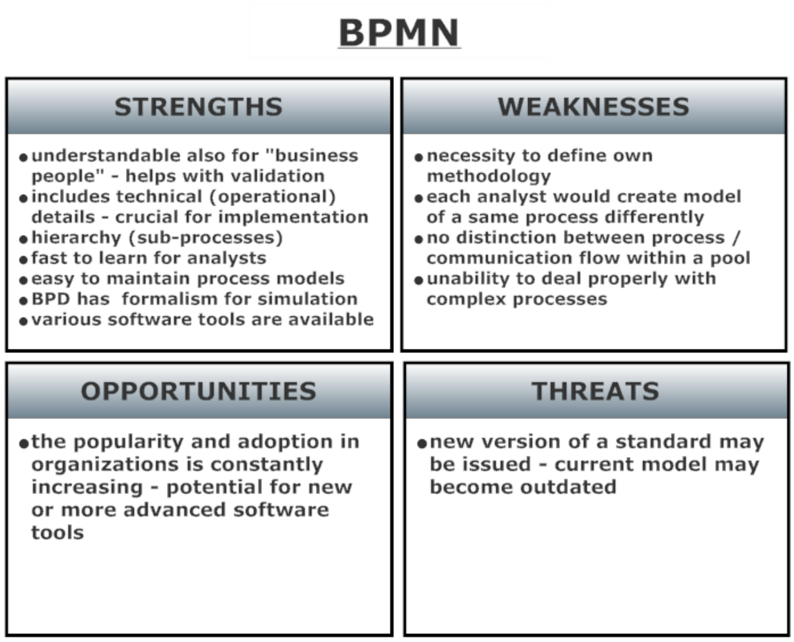


Figure 9.4: The SWOT analysis: BPMN

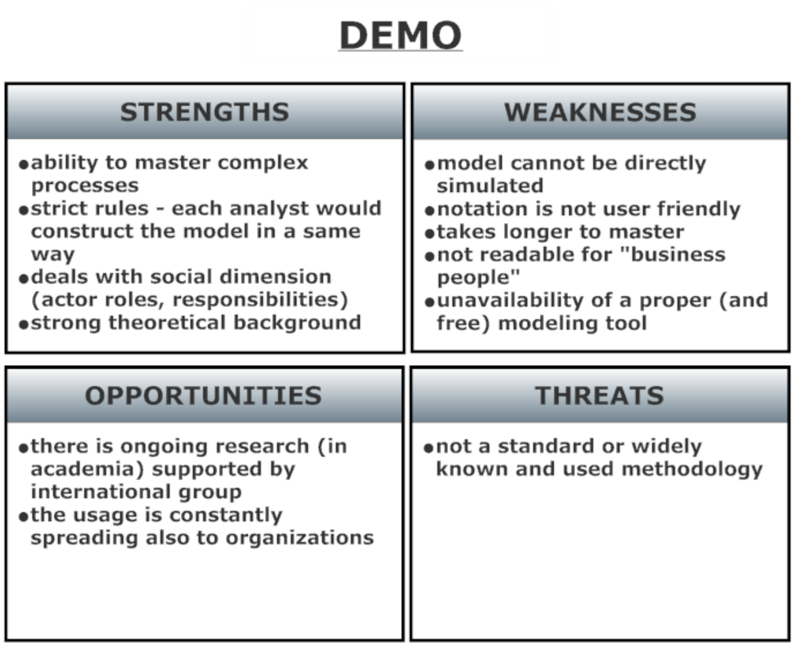


Figure 9.5: The SWOT analysis: DEMO methodology

9.4 Evaluation of BORM, BPMN and DEMO

Evaluating each methodology separately allows to look into the qualities of each from different viewpoints, not in relation to any specific purpose, application, or in comparison with different methodology.

Hommes [48] proposes guidelines for qualitative modeling techniques, which can be takes as an evaluation areas. He also presents a summary (based on literature search) of six commonly measured quality criteria of business process modeling methods. Those are: **completeness, correctness, consistency, minimality, comprehensibility** and **predictive value**.

The guidelines that he proposes include: **notational intuitiveness, syntactic freedom, coherency, determinism, complexity, expressiveness** and **suitability**.

More detailed framework for evaluating BPMo methodologies is presented by Filipowska et al. [38]. The evaluation criteria are divided into three parts: **rationale** (motivation, application and usability); **structure** (completeness and support, extendibility and adaptability) and **quality** (readability and understandability, correctness). Each criteria is further divided into sub-criteria, and to evaluate each sub-criteria a set of questions is provided.

The criteria presented by Hommes [48] are quite general, in comparison to the evaluation framework discussed by Filipowska et al.[38]. The framework is presented rather as a survey for practitioners, and therefore is not suitable for the purpose of this thesis either.

Based on the mentioned quality characteristics of process models and own experience with business process modeling, the following aspects were chosen for the evaluation:

- **Process flow** – *how is the process flow in the model displayed, how are the activities identified, alternative paths defined, and all the possible end states captured?*
- **Communication flow** – *how is the communication between actor roles and flow of information captured?*
- **Actor roles** – *are actor roles assigned to the tasks?*
- **Complexity** – *how complex is the created model, how the methodology deals with complexity of the organization?*
- **Intuitiveness** – *how intuitive is the notation, who are primary users of the model and is the model readable and understandable for them?*
- **Unambiguity** – *how strict are the rules of the notation and the methodology, is there only one way of creating the model?*

- **Simulation** – *is the created model suitable for simulation, can it be translated into Petri net simulation model?*

- **Practical aspects** – *are there SW tools available for modeling, is the created model easy to maintain and how hard is it to master the methodology?*

For each evaluation area, the BORM and DEMO methodologies and the BPMN are evaluated in words, sometimes supplemented with pictures, and are given a score from 1 to 5. The evaluated score states how well is the certain aspect covered in the methodology, *1 – not covered at all, 3 – average (covered, but a lot can be improved), 5 – perfect (almost nothing to improve)*. The evaluation was done based on the description of the methodologies, the case study, own experience and interviews with practitioners[1]. The different aspects are displayed on parts of the case study from Chapter 8.

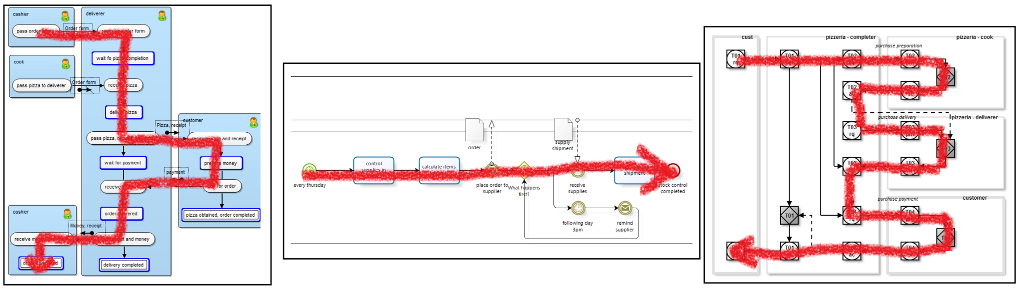
Process flow

BORM
Process flow is covered well, in the main diagram (ORD). It is well visible what is communication, what is transition and involved actor roles. Splits and joins are not included, making the merging problematic - if parts of the process are executed in parallel. Also it does not include specification of for how many of incoming communicational flow links the activity should wait. *Points: 4*

BPMN
Process flow is covered well, in the PSD. Different routing types (gateways) are included, however no distinction of communication within participants is made. *Points: 5*

DEMO
Process flow is visible in the PSD. Each process has its own diagram, parallel routing is included, optional routing is also marked, actor roles depicted. The notation is not very user-friendly. The PSD combines communication and production acts, but this is set by the methodology, and it is clear which step is which. The current version of PSD focuses on displaying the actual process steps. *Points: 5*

[1] BORM: Ing. Robert Pergl, Ph.D., BPMN: Ing. Ondřej Kubera, DEMO: Dr. Joseph Barjis



Process flow: BORM, BPMN, DEMO

Communication flow

BORM

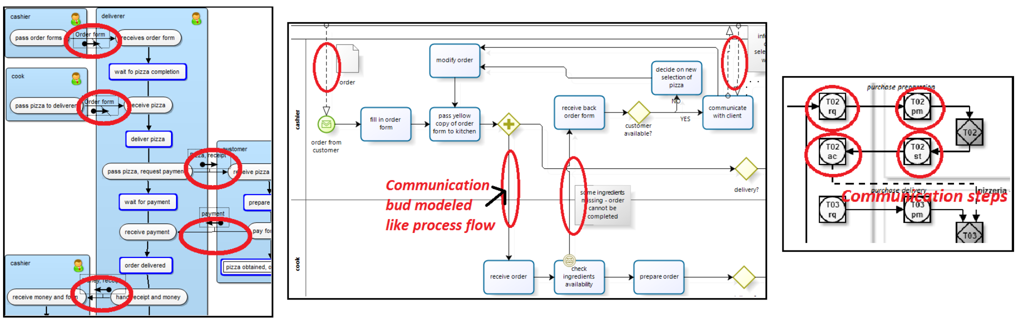
Communication flow is covered in the main diagram (ORD). It is unequivocally distinguished from process flow. A transfer of data / object may be assigned to it, as well as usage of a specific communicational channel. *Points: 5*

BPMN

Communication flow is captured in between the organizations, not within one organization (one swimlane). Data transfer may be assigned to the communication flow. *Points: 2*

DEMO

Transaction axiom specifies the transaction pattern, which always involves communication (request-promise-execution-state-accept), therefore each transaction involves these steps between the initiator and executor. The communicational steps are included in the PSD (currently called as transaction steps diagram). What information or object is transferred is a matter of lower levels of DEMO modeling (I-level and D-level). *Points: 5*



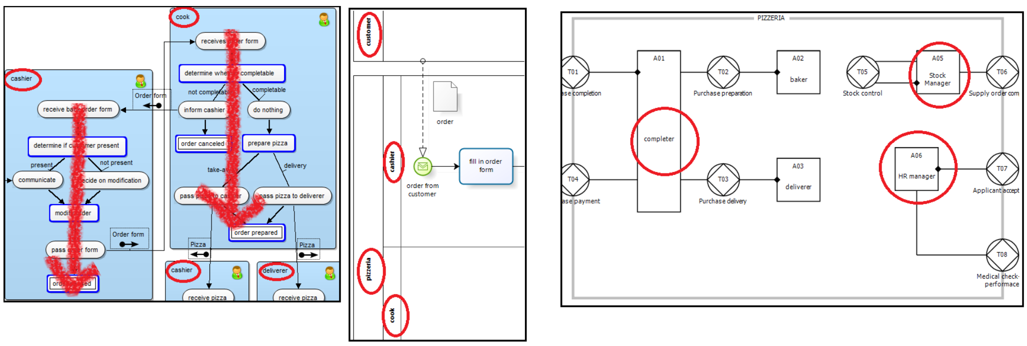
Communication flow: BORM, BPMN, DEMO

Actor roles

BORM
Displays clearly what actor role is involved in which part of the process. The responsibilities of the actor role either start by initiating the process (from state), or by receiving communication flow (from activity). *Points: 5*

BPMN
Actor roles are included, but are only optional. The swimlane normally represents an organization or organizational unit and pools contain actor roles or organizational departments. *Points: 4*

DEMO
Each transaction must have an initiator and executor. One actor role may only once be in the executor role. The responsibilities are clear. *Points: 5*



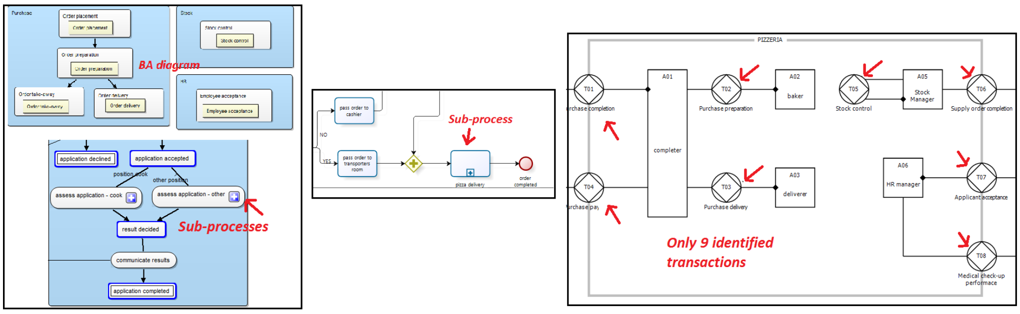
Actor roles: BORM, BPMN, DEMO

Complexity

BORM
BORM allows to split the problem into multiple smaller models. Within one activity, another diagram may be contained (sub-process, or a part of process). To capture the whole organization, a Business Architecture diagram may be used, which plays the role of a process map. The problem is, that the BA looks like a process map, but in fact may only depict one process, which has been split into more diagrams. *Points: 3*

BPMN
BPMN allows and encourages analysts to use hierarchy, where on the top level, a general process is captured, which contains no details. It consists of subprocesses that are modeled in greater detail. The number of layers is not limited. This works well, however, each organization must specify what kinds of activities should be captured at which level. If not done properly, it leads into models that are general, but include some very detailed aspects. *Points: 3*

DEMO
The methodology deals well with the complexity of organizations, by abstracting from implementation and capturing only B-level transactions. The final main diagram (the OCD) even for larger processes would fit on A3 page of paper. *Points: 5*



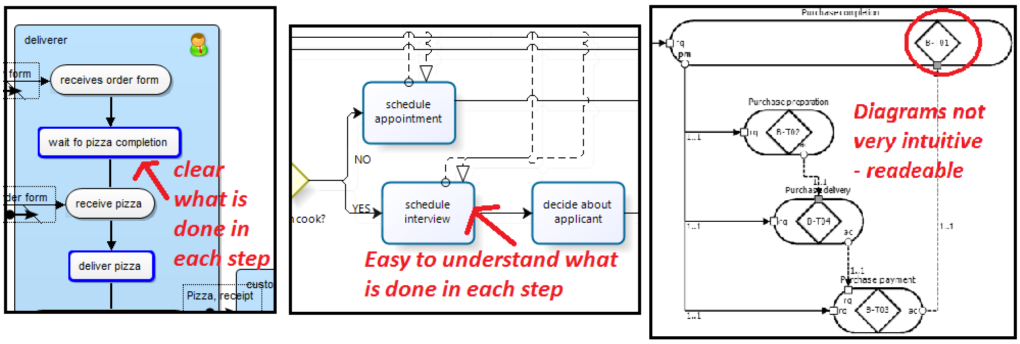
Complexity: BORM, BPMN, DEMO

Intuitiveness

BORM
The BORM model is used by process analysts, "business people" (process owners, maybe also process users) and software engineers. The notation is very intuitive and readable for the whole target group, without deep knowledge of the methodology. The technical details are not included in the notation, but specified textually. *Points: 5*

BPMN
The BPMN model is targeted for developers, who would need it in case the processes are implemented to be executed, and for process analysts and "business people" (process owners and users). The notation is readable even for those unfamiliar with it, but some of the technical details are harder to understand. BPMN allows to model a lot of technical details, which might for business people be confusing. *Points: 4*

DEMO
The DEMO model is intended to be used mainly by process analysts. It might be used by some other people, like software engineers, in case the model would be transformed to Use Cases or used further in another way. The notation is not very intuitive and understandable for those not knowledgeable of it, but as it is simple, it is not hard to master. *Points: 2*



Intuitiveness: BORM, BPMN, DEMO

Unambiguity

BORM

The notation is very simple, but with strict rules. It does not include definition of how the activities and states should be identified, so each analyst may come up with a slightly different model, but at least in all cases, the communication is done between the activities, and those alternate with states. *Points: 3*

BPMN

The notation has strict rules, whatever needs to be modeled can be found in the notation. The lack of methodology causes that each analyst would model the process based on the same description in a different way. Even when using the method described in Chapter 5. The main issues are: 1) specifying the level of modeling (on which level of detail and for who is the model); and 2) displaying activities that are performed tacitly, like receiving a document etc. *Points: 3*

DEMO

The methodology sets strictly the notation, as well as the way of identifying the transactions. Therefore, every DEMO-professional would construct the same DEMO model. *Points: 5*

Simulation

In Chapter 3, two applications of Business Process Simulation were identified – *visualizing the process flow and conducting the performance analysis.* The opportunities each methodology provides is described for each of the usage of BPS. For each methodology, an approach to create a simulation model using totally different tool or simulation technique may be chosen. In this case, it is good to think about the information needed for building a simulation model, and whether it is captured in the process diagram, which is summarized in table 9.13. The items – elements/information needed to build a simulation model, was gained based in literature search in Chapter 3, in table 3.3.

Element / Information	BORM		BPMN		DEMO	diagram
Entities	NO	may be optionally specified, esp. for communication flows	NO	may be optionally specified	YES	IUT (PM)
Activities	YES	ORD	YES	BPD	YES	ATD & TRT (IAM)
Routings (Control-flow)	YES	ORD, but no join for paralel paths	YES	BPD	YES	PM, AM
Resources	YES	participants in ORD	YES	optionally - pool and swimlanes in BPD	YES	ATD (IAM)
Decision rules for decision points	*Described in a table bellow*					
Performance measures	NO		NO		NO	

Data (Attributes of entities must be specified)	PARTLY	may be defined optionally, in a class diagram	PARTLY	may be defined optionally, bude depending on the tool	YES	OPL (SM)
Rules for decision points	YES	ORD	YES	BPD	YES	AM
Probability for taking alternative paths	NO		NO		NO	

Table 9.13: Presence of information needed for simulation in BORM, BPMN and DEMO

BORM
The ORD may be directly simulated. In a simulation software tool, like LINK, the process flow may be visualized. The ORD may be straightforwardly implemented also in Petri net, which would allow a performance analysis of the process. The BORM methodology covers both applications of simulation, but more often is used just the simple simulation – visualizing the process flow, mainly for the purpose of validation of the model. The advantage is, that the model may be directly simulated, so there is no need to construct another simulation model, but not all tools posses the simulation option. *Points: 4*

BPMN
The BPD is suitable for simulation, because the process flow is displayed well. There are lot of software tools available for simulation, which either visualize the process or can be used for performance analysis. BPMN can also be easily translated into Petri net for simulation, but some of its complex aspects might be omitted by the translation. *Points: 4*

DEMO
DEMO model is not suitable for simulation. It has to be transformed into a simulation model, like the one described in Chapter 7. *Points: 2*

Practical aspects

BORM
There is both free and commercial modeling tool available. The created model is easy to maintain using the software tool, except for the situation, where the whole model is divided into few smaller, so some activities need to be included more times. The methodology is easy to learn and master. *Points: 3*

BPMN
There are too many software tools, so a bigger problem than not finding any is choosing the right one. They all include the same notation which is an asset of the BPMN. The model is easy to maintain. Because it is divided into sub-processes, there is no need to duplicate activities. Mastering the advanced elements of the BPMN takes some effort, but is not extremely difficult. *Points: 5*

DEMO
Unfortunately, only one commercial and no free software tools are available for DEMO (except for one online, which is still a test-version). The DEMO model consists of 4 aspect models and each has more diagrams or tables, so the maintenance is not easy, but the software tool helps with that, and applies some of the changes made in the other models. The methodology is hard to master, as it is very complex and requires deep understating of the theoretical foundations. *Points: 2*

The BORM methodology gained 32 points, the DEMO methodology 31 and the BPMN 30. More interesting, however, are the partial results. **In each of the evaluated criteria, besides simulation, one methodology gained the highest score.** As stated earlier in this chapter, the BORM methodology and the BPMN are more similar to each other, and this can be seen from the results of the evaluation also – the difference in scoring in each aspect between them is in most cases 1 or 0 points. **The DEMO methodology is always better than both the BORM methodology and the BPMN, or worse than both, never in the middle, which confirms the theoretical conclusions, that DEMO methodology is different from the two others.** This may be visible in figure 9.6.

Interesting is, that the **DEMO methodology** always scored 5 or 2 points, **meaning some of the evaluated aspects are perfect, while some were**

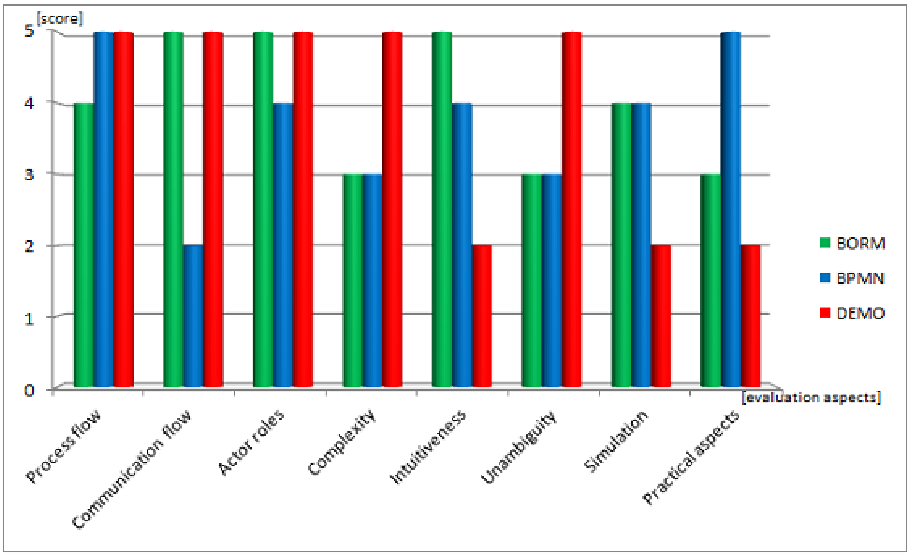


Figure 9.6: Results of evaluation of BORM, BPMN and DEMO

almost not taken into account. This confirms, that the methodology was developed properly, and what it was supposed to include, is covered and solved precisely. **The aspects that scored low (Intuitiveness, Simulation and Practical aspect), are not considered important by the authors of the methodology.** Intuitiveness scored low, because the DEMO methodology is not designated to the end users. The simulation, however, would be beneficial, even on the organizational level and is considered a main drawback of the DEMO methodology. Practical aspects, like availability of software tools, definitely influence the extent and speed with which the methodology is spread among users and organizations.

The **BORM methodology also jumps from 3 to 5 points, which shows that some aspects were developed precisely, some are lacking a lot,** but they are covered, which means they were not omitted on purpose. The BORM methodology has **a space for improvement mainly in dealing with complexity and ambiguity of the created model, practical aspects,** like model maintenance and **process flow** – splits and joins, namely joining the parallel paths.

In case of the **BPMN**, most aspects were evaluated by 3 or 4 points. **It is intended to solve all aspects of the evaluation, but has some space for improvement in most. Namely the top three candidates for improvements are communication flow, ambiguity of the model and complexity.** The communication flow is a matter of the BPMN standard, and it is surprising, that it does not allow to model communication (or information) flow within one organization (one swimlane). Anyhow, if displaying the communication flow would be crucial, it can be solved by modeling each participant in a different swimlane. The ambiguity and complexity go together, and are a result of lacking modeling methodology. Even though the method and style defines some rules for creating "good BPMN", still each modeler has to set the level of detail and a way of identifying the activities.

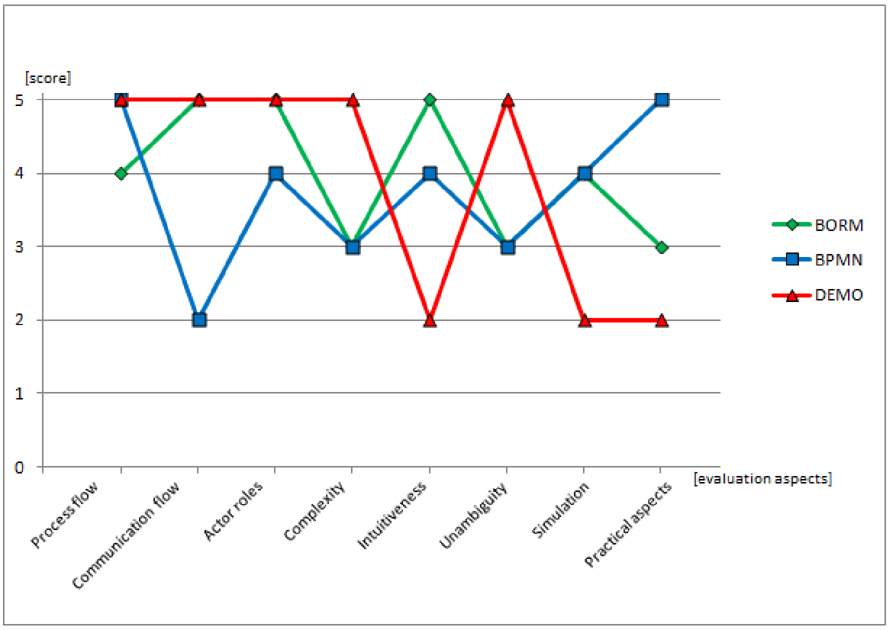


Figure 9.7: Results of evaluation of BORM, BPMN and DEMO - range of points

9.5 Summary

The BORM and DEMO methodologies and the BPMN were evaluated and compared, based on the case example and theoretical background presented Chapter 2. Results of the evaluation were discussed, with suggestions for improvement. **Even though each was developed with a different purpose, the BORM methodology and the BPMN are similar in many aspects. The DEMO methodology proved to be different, not only from the theoretical perspective, but also from the evaluation by scoring high where the BORM methodology and the BPMN scored low, and the other way round.**

Knowing the differences and similarities is not as important as understanding the application and being able to decide which one to choose for which situation in the organization. The level of applicability for different usages of process modeling was displayed in figure 9.1. To have a more general comparison, then by single identified areas of usage, figure 9.9 displays the applicability of the BORM and DEMO methodologies and the BPMN for each category and figure 9.8 for each level of organizational management.

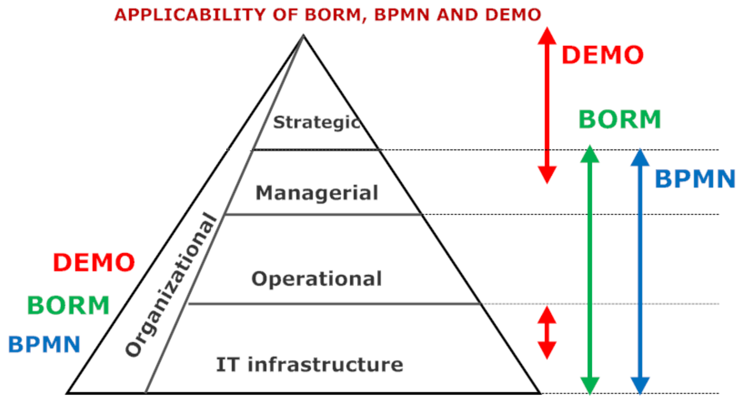


Figure 9.8: Applicability of BORM, BPMN and DEMO for organizational management levels

In case of the DEMO methodology, it is interesting that it covers the very top of the pyramid and then the very bottom (the IT infrastructure). The IT Infrastructure is included because the DEMO model may be transformed into use case model or used for requirements engineering. It is, however, important to keep in mind, that in either case, the DEMO model captures the ontological level of the organization.

When choosing a Business Process Modeling methodology, all application, organizational level and purpose can be taken into account. If the intended usage is clear, the methodology can be selected based on that. Often it is not so straightforward, because the organization wants to use the process models in multiple ways, but nobody wants to have three process models – one in each methodology. The choice in such a case should be done based on the categories of business process modeling benefits – in which areas of the organizational management lie the expected benefits and by purpose of the process modeling project. The goal is to find a methodology that covers all areas identified as necessary.

For example modeling business processes in order to present the process and communication flow and to simulate and improve the processes, involves the operational, managerial as well as organizational level, and purpose of presenting

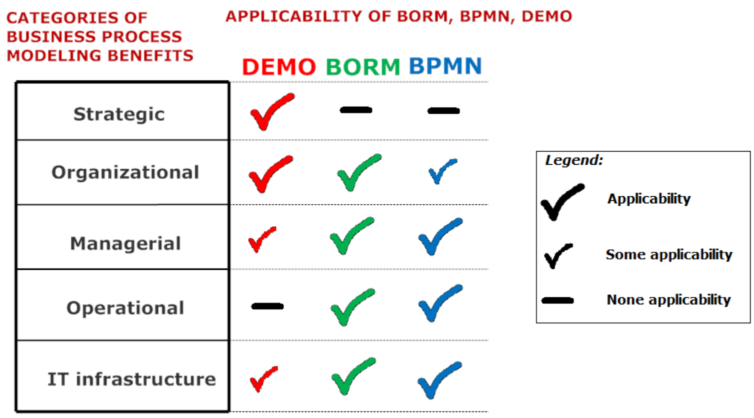


Figure 9.9: Applicability of BORM, BPMN and DEMO in relation to categories of BPMo benefits

and analyzing. According to figure 9.9, both BORM methodology and the BPMN may be used, but due to the desire to capture communication flow, the BORM methodology would be the right choice, unless very technical details have to be included. This shows, that the final decision should be done, considering both aspects of the comparison – the categories of business process modeling benefits and the purpose.

The big difference between the DEMO methodology and the BORM methodology and the BPMN, which is also visible in the results of the evaluation, leads into a consideration, that **the methodologies may complete each other in some aspects, rather than compete with each other**. This definitely is an interesting conclusion, and is further very briefly discussed in a following chapter.

Chapter **10**

Combination

The DEMO methodology ends, where the BPMN starts, so instead of competing, they can be used together [9]. The DEMO methodology, which is based on the PSI theory, gives consistent, implementation independent view on the organization and its business processes. All axioms are equally important, but in comparison with the BORM methodology and the BPMN, the *Transaction axiom* is the most unique one. The *Operation axiom*, which defines the actor roles (initiator and executor) is partly present also in the BORM methodology and the BPMN – they both allow specifying actor roles. The *Composition axiom*, that defines the composition (order and relationship) of transactions, is defined neither in the BORM methodology nor in the BPMN, but the final process flow includes the activities in an appropriate order. The *Distinction axiom* and the *Organizational theorem* divide the organization and acts into three level – *ontological, infological* and *datalogical*. That determines the level of process modeling, and captured activities, but does not influence the modeled process flow.

Cetano et al. [9] compares the DEMO methodology with the BPMN, and according to him, the **DEMO methodology focuses on why and how people communicate and cooperate**, which is theoretically supported by the Transaction axiom, while the **BPMN focuses on specifying the flow of activities and information**. The BPMN does not provide the means to assess the actual consistency and completeness of business process, in comparison to the DEMO methodology. The DEMO aims at analyzing the consistency, by which is meant the possibility to translate it to business transaction steps, and completeness, which involves specification of all required activities [9].

The DEMO model needs to be supplemented by functionally oriented models, with infological and datalogical aspects and implementation oriented processes and ICT models [32] - it ends, where the BPMN starts. The figure 10.1 displays the relation between the BORM and DEMO methodologies and the BPMN. Process modeling project may be divided into three phases. The first one captures the process on the ontological level and aims at abstraction from implementation.

The second one captures the processes on the operational level and includes all the operational level details, like timer, waiting etc. The third one specifies all the technical and operational details, like time period, type of message flows etc.

For example the BPMN would on the first level be used for constructing a process map, but that is exactly when the DEMO methodology may be used instead, because it covers a way of identifying the ontological transactions. In the second phase, BPMN includes elements often known as a ***palette level 1*** and in the third phase elements from the so-called ***pallet level 2*** and details like exact timer specifications, events etc. The BORM methodology bridges the usage of the DEMO methodology and the BPMN. The BORM model is conceptual, but includes some implementation aspects and some operational details.

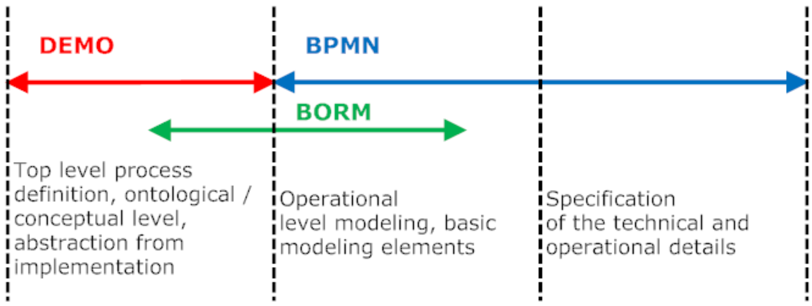


Figure 10.1: Relation between BORM, BPMN and DEMO

10.1 The DEMO methodology and the BPMN

The DEMO methodology can be used with the BPMN in two ways:

1. The DEMO model as an input into the BPMN modeling project
2. The DEMO methodology concepts are used to improve consistency of the BPMN models

10.1.1 The DEMO model as an input into the BPMN modeling project

The DEMO methodology specifies the process on the ontological level, but each transaction, identified the DEMO methodology, may consist of multiple steps, on the lower levels. For example in case of the pizzeria case example, presented in Chapter 8, the transaction *Pizza baking*, or *Pizza delivery* consists of more steps. For example pizza delivery consists of the actual delivery, payment, receipt signature etc. If these need to be specified in details, the BPMN can be used.

10.1.2 The DEMO methodology concepts are used to improve consistency of the BPMN models

The DEMO's *Transaction axiom* is used to specify the ontological transaction. According to the definition, each transaction consists of 5 steps: *request, promise, execution, state* and *accept*. Execution is a **production step**, the other are **communicational steps**. The transaction axiom allows identifying all transaction steps, even those performed tacitly, which is what is lacking in the BPMN. Using the transaction axiom, where always the set of 5 steps is captured, would ensure the model consistency.

Looking back at the BPD Pizza completion, not all transaction steps are included, which is visible in figure 10.2, which takes part of the *Pizza completion* process, namely the *pizza delivery* part. There are two transactions - pizza delivery and purchase. If used the DEMO's Transaction axiom, missing are transaction steps: *delivery promise, payment promise*. The promise of payment is very likely done tacitly, just by words. However in case of promising delivery, passing of the order form is involved. In this diagram, the action "receive order form" is not modeled, but surely could be, which shows, that the final BPD is not unambiguous. However, enhancing it with the Transaction axiom, would solve this issue. The enhanced part of this diagram is displayed in figure 10.3.

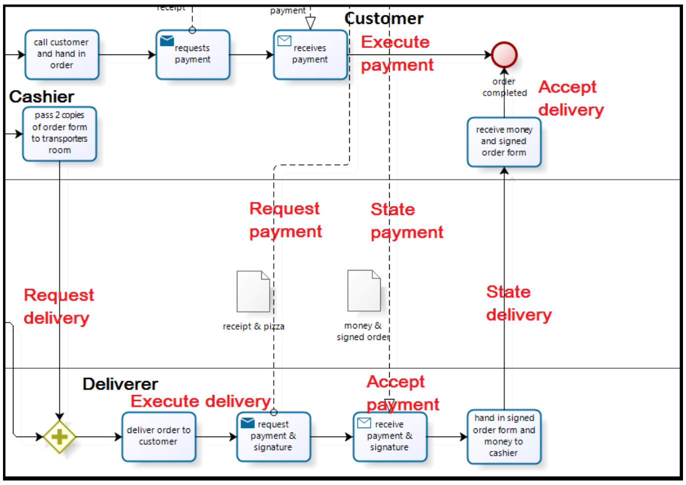


Figure 10.2: The BPD and the Transaction axiom

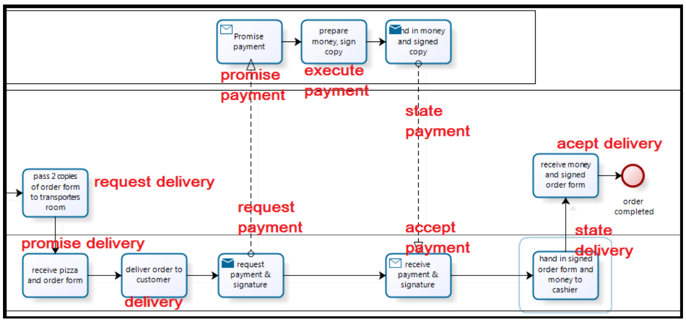


Figure 10.3: Improving the BPD by the Transaction axiom

10.2 The DEMO and BORM methodologies

The BORM methodology is on the border of the DEMO methodology and the BPMN, but is not as perfect as the DEMO methodology combined with the BPMN. In the BORM's BA diagram, the top level process is specified. To identify the key ontological transactions, which is not part of the the BORM methodology, the DEMO's *Performa-Informa-Forma* analysis may be used. The ontological transactions can then be specified in the BA diagram, and the operational level processes in the regular ORD. By this, the BORM methodology could be enhanced, because it would be clearly set which transactions should be included in the BA diagram.

The transaction axiom is not defined in the BORM, but the methodology works in a very similar way, which is visible in figure 10.4 on the *Stock control* transaction. Because the communication between participants is captured, each communication flow happens both ways, which is in the DEMO methodology represented as a pair *request-promise*, or the so-called *O-phase*. Then some other steps, which can be called execution phase, are performed. The result may be communicated back to the requester, so again the communication flow is like the *state-accept*, or so called *R-phase* of the DEMO methodology.

There are two difference here, between the BORM and DEMO methodologies:

1. The communicational steps are not obligatory, process may be initiated and executed within one participant
2. The execution may include multiple steps

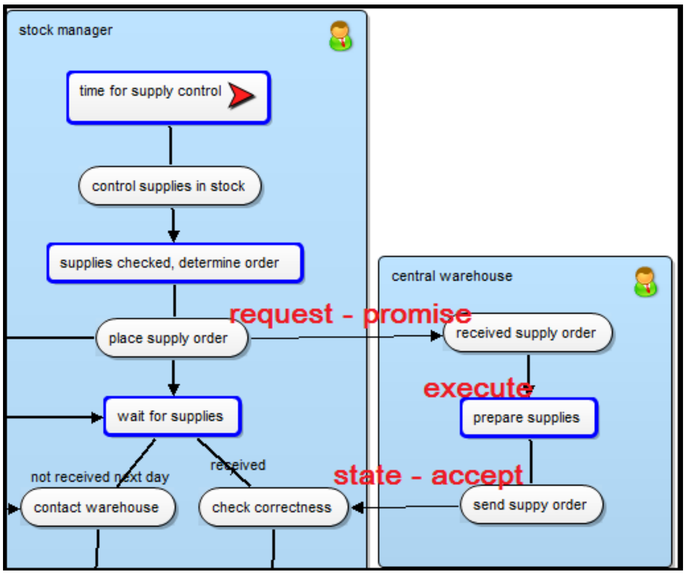


Figure 10.4: The Transaction axiom in the ORD

10.3 Summary

The DEMO methodology, due to its theoretical background, may be used to enhance the BORM methodology and the BPMN. The main two applications are usage of the ***Performa-Informa-Forma*** analysis to identify the ontological transactions, that could be included in the top level diagram or process map, and usage of the ***Transaction axiom***, that specifies the transaction steps, leading into identification of all process steps, even those performed tacitly.

Chapter **11**

Summary and conclusion

The aim of this thesis was to analyze advantages and strengths of the BORM methodology, the BPMN and the DEMO methodology, to study application and purposes of Business Process Modeling and to investigate which of the three would be suitable for particular purposes. Furthermore, because simulation plays an important role in (re)designing business processes and Business Process Modeling should always be complemented with simulation, another goal was to regard the methodologies not only as mere modeling methodologies, but also to asses their suitability for simulation. Because the DEMO methodology is the only one which does not support simulation, a second objective of this thesis was to propose a method of translating a DEMO model into a Petri net simulation model. The Petri net technique was chosen since it has proved suitable for modeling workflows.

11.1 Summary of the results

This section summarizes the results of the comparison, evaluation and suitability for each identified purpose and organizational management level. It is important to keep in mind that the choice of the modeling methodology should be always done in relation to the purpose of the Business Process Modeling project.

The three main identified purposes of Business Process Modeling are: **Analyzing**, for which the BORM and DEMO methodologies are most useful because the capture well both the process flow and communication flow; **Capturing**, for which the BORM methodology is most often used as the one producing the most suitable diagram for further software implementation; and **Presenting**, for which the BPMN is the number one technique, due to its readability and understandability for both "business people" and "technical people".

Looking at the applicability of the three methodologies in relation to the organizational management level, 5 categories were identified - ***strategic, ma-***

nagerial (tactical), operational, IT infrastructure and ***organizational level***. The DEMO methodology is suitable for the strategic, managerial, organizational, and partly IT infrastructure levels, the BORM methodology for the managerial, organizational, operational and IT infrastructure levels and the BPMN for the managerial, operational, IT infrastructure and partly organizational levels.

The DEMO methodology captures processes on an ontological level and therefore would be of biggest help for strategic planning and decision-making, while the BORM methodology and the BPMN deal with processes on the operational level. The BORM methodology would be more suitable for software development projects, in correspondence with its primary purpose, while the BPMN can find higher usage in the area of process documentation and process-oriented software implementation, because process models include all the necessary technical details. This corresponds to the three areas, in relation to which the processes are modeled (figure 11.1): the DEMO methodology is primarily applied in Enterprise Engineering, the BORM methodology in Software Engineering, and the BPMN in Business Process Engineering.

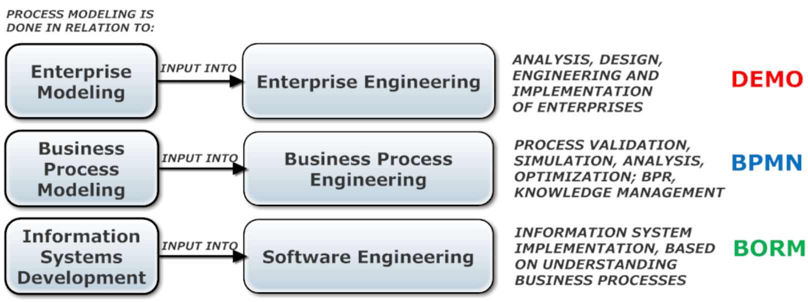


Figure 11.1: Applicability: BORM, BPMN, DEMO

The DEMO methodology should not be seen not as a competitor of the BPMN and the BORM methodology, but rather as a methodology that may complement them. Implementation-oriented models like the BPMN model can be enriched by the DEMO methodology's concepts like, for example, the transaction axiom.

The comparison of the BORM methodology, the BPMN and the DEMO methodology yields following results:

- Advantage of the **BORM methodology over the BPMN** is that the BORM methodology clearly distinguishes communication flow and process sequence flow, and defines what actor role or object is responsible for which part of the process.
- Advantage of the **BORM methodology over the DEMO methodology** is that the BORM model (ORD) is more intuitive and understandable

and may be directly simulated.

- Advantage of the **BPMN over the BORM methodology** is that the BPMN captures more technical, operational details, which is helpful if processes are implemented for execution.
- Advantage of the **BPMN over the DEMO methodology** is that it is more understandable to "non-technical" people.
- Advantage of the **DEMO methodology over the BORM methodology and the BPMN** is that the DEMO methodology captures processes on the ontological level with abstraction from implementation, which reduces the complexity of the model. Due to its theoretical background and strict rules, the created process models are unambiguous.

Simulation may be used either to visualize the process flow, or to conduct a performance analysis. The first offers a tremendous help in validating the process with process owners, users and analysts. The second allows to identify the throughput times, bottlenecks, etc. as a first step in process improvement.

To know which specific information is needed in order to build a simulation model is considered a prerequisite of a simulation study. If the model is to be used only to visualize the process flow, we only need activities, routings, elements flowing through the system, resources and decision rules. This information is captured in both the BORM and DEMO methodologies and in the BPMN, namely in the ORD (BORM), PSD and ATD (DEMO) and BPD (BPMN). For performance analysis, the performance measures, like activity times, number of resources, probabilities for the decision points, case generation scheme etc. would have to be specified. Those are not included in any of the methodologies.

Both the BPD (BPMN) and the ORD (BORM) may be directly simulated, using software tools intended for that purpose. The DEMO model does not support simulation. To solve this drawback, the approach of translating the DEMO model into the Petri net model was chosen. The method consists of a set of modeling constructs of DEMO's Process Structure Diagram, which is taken as the main input, and corresponding modeling constructs in the Petri net. The method was developed by translating multiple examples of various size and type, which are included on the CD attached. Prior to that, the information needed to build a simulation model has been researched and information included in the DEMO model analyzed. The Petri net model obtained has utilization in both mentioned areas of applicability of simulation.

11.2 Future research

Business Process Modeling and Simulation is a wide area offering a lot of possibilities for future research. Since this thesis focused only on the BORM and

DEMO methodologies and the BPMN, it would be interesting to include more methodologies which can be compared on the basis of the same aspects - the purpose and application of Business Process Modeling, as this was quite extensively covered in Chapter 2.

The application was presented only on a case study of a small size. It would be interesting to take the proposed identified applicability of the BORM and DEMO methodologies and the BPMN and investigate its accuracy on a larger case example, or ideally on a real organization.

Furthermore, because one of the conclusions was that the DEMO methodology may be used together with the BPMN and partly with BORM, but discussed only very briefly, those would be definitely interesting topics for further research.

Finally, there are a lot of research options in the area of Business Process Simulation. Namely in relation to this thesis, looking back at the Petri net simulation, the hierarchy aspect of the Petri net allows to model a task in a greater detail, which could be used to specify the actual production steps within the task. Translating the DEMO model into the Petri net model, therefore, could be considered as the first step in integrating the organizational processes and production processes for the purpose of their modeling and simulation.

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Appendix A

Acronyms

ABD Actor Bank Diagram

ABM Agent Based Modeling

ABS Agent Based Simulation

AM Action Model

ATD Actor Transaction Diagram

BAM Business Activity Monitoring

BCT Bank Contents Table

BO Business Object

BORM Business Object Relationship Modelling

BPA Business Process Analysis

BPD Business Process Diagram

BPM Business Process Management

BPMI Business Process Management Initiative

BPMN Business Process Modeling Notation

BPMo Business Process Modeling

BPR Business Process Reengineering

BPS Business Process Simulation

CM Construction Model

CO Conceptual Object

DEMO Design and Engineering Methodology for Organizations

DES Discrete Event Simulation

IAM Interaction Model

IS Information System

ISM Interstriction model

IUT Information Use Table

OBA Object Behavioral Analysis

OFD Object Fact Diagram

OMG Object Management Group

OOA&D Object Oriented Analysis and Design

OPL Object Property List

ORD Object Relationship Diagram

PM Process Model

PSD Process Structure Diagram

SM State Model

SO Software Object

SWOT Strengths - Weaknesses - Opportunities - Threads

TRT Transaction Result Table

UML Unified Modelling Language

Wf Workflow

WfM Workflow Management

WfMC Workflow Management Coalition

WfMS Workflow Management System

XML Extensible Markup Language

APPENDIX B

Definitions

ARIS Business process modeling method as well as free modeling tool

Event Driven Process Chain - EPC A graphical modeling language used for flowcharting and

Action or Activity Diagram - AD Graphical representations of workflows

Business Process Query Language - BPQL Process diagnosis standard, interface to a business process management

ER-modeling Entity-Relationship modeling, a way to describe relation between objects or data

IDEF0, IDEF3 Business process modeling methods

I/O flow Input / Output flow - process modeling technique

Petri Net - PN, Colored Petri Net - CPN Technique for modeling and simulating workflows, based on alternating elements - places and transitions

Role Activity Diagram - RAD A way of describing processes, focused on roles and their activities

Role Interaction Nets Graphical representation of a net, set of agents and set of rules between the agents

Web Services Flow Language - WSFL Process execution standard, XML language for the description of Web Services compositions

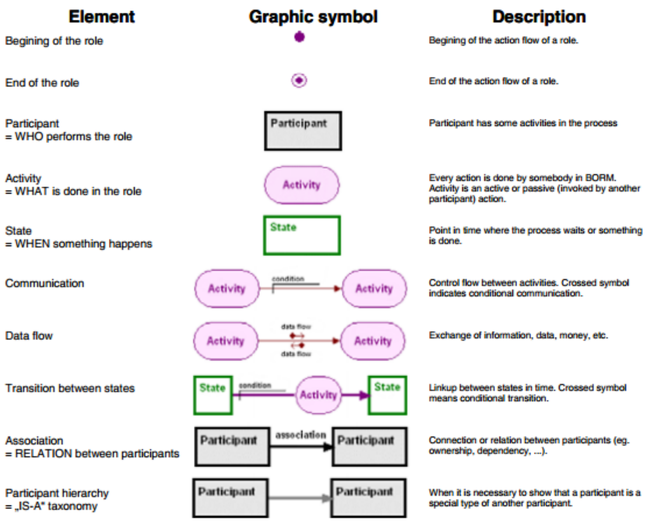
Xlang Process execution standard, an XML-based extension of Web Services Description Language

XPDL - XML Process Definition Language Process execution standard

Appendix C

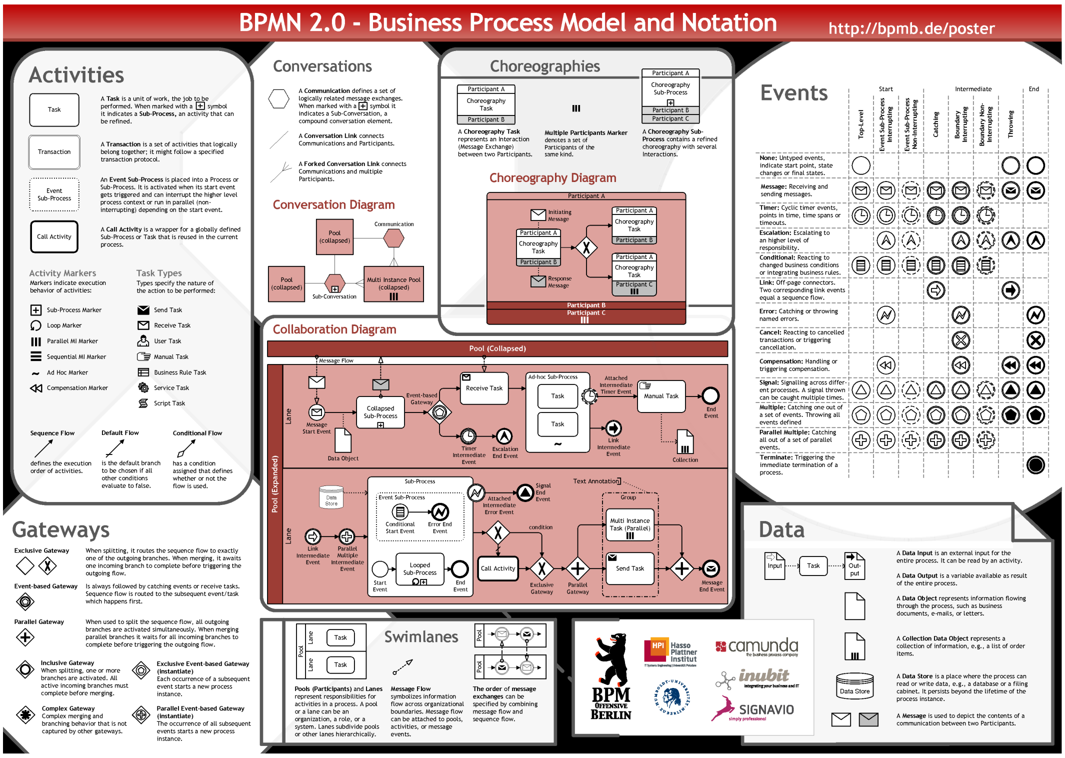
Notation of BORM, BPMN, DEMO

C.1 BORM



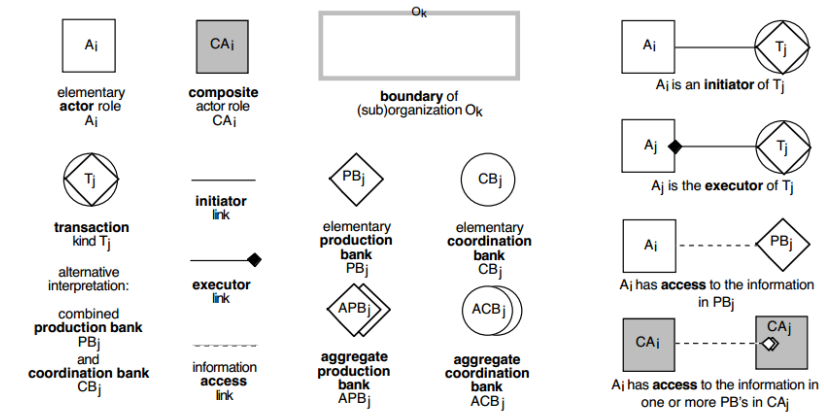
C.2 BPMN

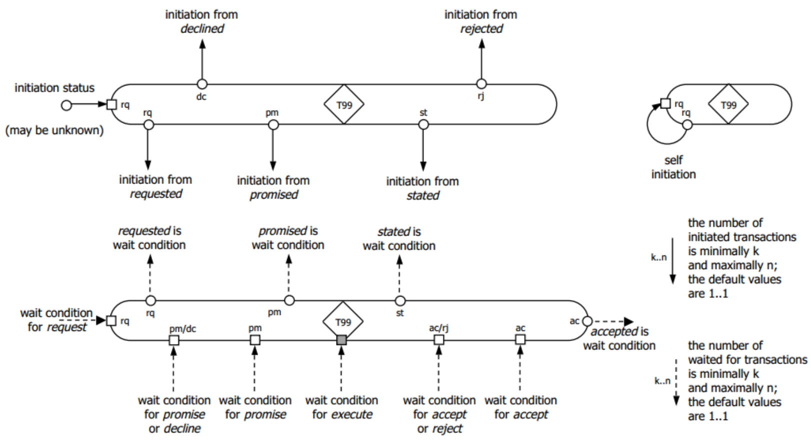
The Business Process Modeling Notation is very extensive, therefore a poster with the notation overview in a full resolution is included on the attached CD [17].



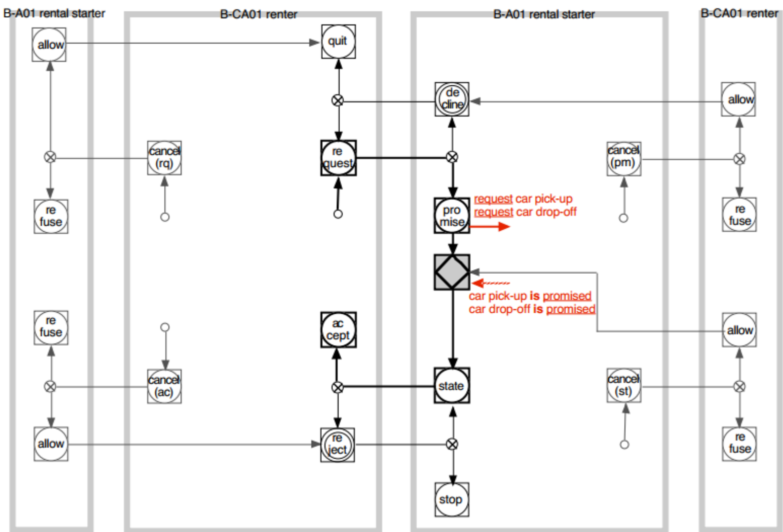
C.3 DEMO

The notation of the DEMO methodology is also extensive, because it includes muplitple aspect models. The most commonly used aspect models (The Organization Construction Diagram, the Process Structure Diagram and the detailed Transaction pattern) is included in this section, based on [33]. Detailed notation is on the attached CD.





The 'sausage' is an 'extracted' transaction symbol. The diamond remains unchanged.
There is an invisible, non-proportional, time line from left to right. So, process steps occur in the order they have in the (standard) transaction pattern.


B-A01 rental starter
B-CA01 renter
B-A01 rental starter
B-CA01 renter
allow
quit
de cline
allow
cancel (rq)
re quest
cancel (pm)
re fuse
pro mise
request car pick-up
request car drop-off
re fuse
car pick-up is promised
car drop-off is promised
re fuse
ac cept
allow
cancel (ac)
state
cancel (st)
allow
re ject
re fuse
stop

Appendix **D**

Contents of enclosed CD

- `readme.txt` .... the file with CD contents description
- `src` .... the directory of source codes
  - `thesis` .... the directory of LaTeX source codes of the thesis
- `text` ....the thesis text directory
  - `thesis.pdf` .... the thesis text in PDF format
  - `thesis.ps` .... the thesis text in PS format
- `other` .... other materials directory
  - `petri-net-model` .. the direcotry with Petri net models in the CPN Tools
  - `notation` ... the directory with the notation of the BORM, BPMN, DEMO
  - `case-study` .... the directory with models used in case study