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On the Structure and Use of Process Models and Their Interplay

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ABSTRACT

A picture is worth a thousand words, but a few words can greatly enhance a picture. It is common to find textual and diagrammatic components complementing each other in enterprise models in general, and business process models in particular. Previous studies have considered the question of the relative understandability of diagrammatic versus textual representations of process models for different types of users. However, the effect of combining textual and diagrammatic components on the actual use and reuse of process models has received little attention.

In this setting, this thesis approaches the questions of: (i) how do structured and unstructured components of process models co-exist with each other in practice; and (ii) what determines that a process model is used on a sustained basis within an organization? These two questions are first approached separately, and then jointly, via three complementary studies.

The first study focuses on the co-existence of different types of process documentation structures within an organization. Specifically, this study proposes a framework, namely the Process Documentation Cube (PDC) for mapping and assessing business process documentation with the aim of identifying gaps and potential inconsistencies. The PDC framework is built on the principle that documentation should exist in an organization at different levels of detail, across different organizational areas and in different formats, ranging from unstructured text to structured artifacts such as tables and diagrams. Accordingly, the PDC framework combines three assessment dimensions: granularity, organizational area and structure. The suitability of PDC to support process documentation mapping and planning efforts is validated via a series of case studies.

The second study focuses on the identification of factors that affect the sustained use of process models in an organization. First, the study puts forward a priori model of sustained process model use derived from existing factor models of business process modelling success and reuse. This model is packaged as an assessment instrument and applied to four organizations from different domains. Based on these case studies, a subset of factors and relationships are identified, which collectively explain differences in the observed sustained use of process models across the organizations in question.

The third study bridges across the two above-mentioned questions. Specifically, this study addresses the question of how the mix of diagrammatic and textual components in business process models affects their sustained use. This question is approached by means of a case study in a telecommunications company where models with different mixtures of text and diagrams have been collected over time. The study shows that models where diagrams are used to capture ordering relations between activities at a granular level, while text is used at a more detailed level, are more likely to be used on a sustained basis. The latter finding emphasizes the potential benefits of considering different documentation formats not as alternative, but as complementary parts of a whole.

FOREWORD

My thesis was "triggered" by 18 years of work in the business consultancy sector. In the course of these years, my company implemented different system analysis projects (altogether more than 100) with the aim to organize the data, processes and information systems of various organizations. Many projects predated the development or introduction of IT solutions; at the same time, the aim of most of the projects was to solve the problems of a specific area and to improve the efficiency of processes. The more projects were completed, the more I started to ponder: Why, despite these projects being considered successful by the relevant stakeholders, the (process) models that we had created were not being used in the long-term after the end of the projects? In many cases, the feedback we were getting is that the models we had produced during the projects (especially the diagrammatic models) were well-organized and provided a comprehensive and accurate view of critical processes of the business.

Naturally, we came up with many hypotheses as to why this could be the case: keeping the models up-to-date is time-consuming; the notation used in the diagrammatic models we produced was often unfamiliar to potential users, who might instead prefer textual documents; the tools for storing and managing these models were not well mastered in the organization; the projects were too short to be able to offer a sensible plan for the ongoing management of the processes we improved, and thus the stakeholders did not feel a need to use the models we left behind in the long-term. But besides generating plausible hypotheses, we were unable to identify a clear set of roadblocks towards the sustained use of the (process) models we produced in our projects.

Some of our client organizations did manage to continue using the process models we left behind in the long-term. But no clear recipe came out of these cases. What was clear is that simply "copying" the positive experience of an organization and applying it to another organization would not work – there were too many factors to be taken into account: the size of the organization, the attitude of employees, the management style, the organization's experience in knowledge management, etc.

Thus, I became interested in researching the subject of how to ensure that process models created during a given project continue to be used widely and in the long-run.

Another question which, as the previous one, had arisen over the years, was related to the format of the process models we were producing. When the analysis result was used by software designers and programmers in the context of an IT-project, express preference was given to diagrams which enable to present important information precisely and unambiguously. In models used in consultancy projects oriented at business people, diagrams were also useful in bringing out complex relations and in presenting the structures of different objects in a simpler manner, but it was far more complicated to find a balance between structured information (diagrams) and information presented only in textual form. We hypothesized that the diagrams we were producing (using well-known process modelling notations) were perceived to be too technical by "regular" users, more accustomed to reading textual descriptions. On the other hand, the stakeholders involved in the project perceived that the structured descriptions (diagrams and tables) we were producing, gave them a clearer and more readable view of their processes, compared with the textual descriptions.

This experience led me to think that the two question of how to make process models be used on a sustained basis is intertwined with that of how to trade-off the perceived advantages of structured (diagrammatic or tabular) process descriptions, and those of unstructured (textual) process descriptions.

What follows is the result of my quest to give shape and test some of the hypotheses mentioned above – and other questions I came across during my PhD studies.

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People in my circle have played an important role in the completion of my doctoral thesis. They have supported me during the last five years in carrying out the studies and contributed to the refinement of my ideas.

I am most thankful to my supervisor Marlon Dumas who has been a role model for me with his deep and extensive knowledge and outlook on life both in professional as well as personal terms. My supervisor has been a valuable co-thinker and evaluator of ideas as regards connecting the academic and operational perspectives in order to achieve academically acceptable results which, at the same time, benefit the organizations participating in the study.

I would very much like to thank all organizations and experts who agreed to dedicate their time to the case studies I conducted. Usually, it could not be predicted at the very beginning of the study to what extent the organization would benefit from the time dedicated to the study and what would be the expected results. As the experts were extremely busy, I value their readiness to participate in studies even more. I do believe, however, that the cooperation process was interesting and useful as we tested methods which were new and innovative for all parties.

And my most sincere thanks goes to my family who supported me during the whole period of my studies and helped me during the period of completing my doctorate as well. I am most thankful to my wife who was the first reviewer of many new topics and provided her support.

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LIST OF ORIGINAL PUBLICATIONS

- Saarsen, Toomas; Dumas, Marlon "The Process Documentation Cube: A Model for Process Documentation Assessment" *In Proceedings of the Business Process Management Workshops (BPM Workshops)*. Springer Berlin Heidelberg, 2012, pp. 501–512.
  - I am the main author of this paper. I conceived the initial idea of the documentation cube framework and developed the framework with minimal advice from the second author. I designed and conducted the case studies. I wrote a full draft of the paper myself and I improved it with feedback from the second author. About 80% of the ideas and the write-up of this paper come from me.
- Saarsen, Toomas; Dumas, Marlon "Towards an assessment model for balancing process model production and use" *In Proceedings of the ACM Symposium on Applied Computing* (ACM SAC). ACM Press, 2014, pp. 1386–1392.
  - I am the main author of this paper. I conceived and developed the assessment model with minimal advice from the second author. I designed and conducted the case studies. I wrote a full draft of the paper myself and I improved it with feedback from the second author. About 90% of the ideas and the write-up of this paper come from me.
- Saarsen, Toomas; Dumas, Marlon: "Factors Affecting the Sustained Use of Process Models" *In Proceedings of the Business Process Management Forum (BPM Forum)*. Springer International Publishing, 2016, pp. 193–209.
  - I am the main author of this paper. I framed the research questions and developed the sustained use model with minimal advice from the second author. I designed and conducted the case studies. I wrote a full draft of the paper myself and I improved it with feedback from the second author. About 80% of the ideas and the write-up of this paper come from me.
- Saarsen, Toomas; Dumas, Marlon: "On the Effect of Mixing Text and Diagrams on Business Process Model Use" *In Proceedings of the European Conference on Information Systems (ECIS)*. Association for Information Systems (AIS), 2017. Accepted for publication.
  - I am the main author of this paper. I framed the research questions and designed and conducted the study. I wrote a full draft of the paper myself and I improved it with feedback from the second author. About 80% of the ideas and the write-up of this paper come from me.

1. INTRODUCTION

Visual tools began to be used for describing complex systems already more than 100 years ago – Gantt charts [1] came into use approximately in 1890, flow charts [2] a few decades later. Process modelling in the modern sense was first mentioned by S. Williams in his article in 1967 [3]. A more active substantive development of the field of process modelling began approximately 20 years later, motivated by the need for describing and analysing complex processes by different user groups. During the last two decades, this field has developed rapidly thanks to increasing competition in different business sectors and radical improvement opportunities created by digitization.

Business processes modelling has been part of mainstream Information Technology (IT) system development methodologies for around twenty years already [4]. During this time, the landscape of process modelling tools has developed at a sustained pace, driven by the commoditization of hardware and software frameworks providing advanced graphical display and editing capabilities, and the commoditization of network technology enabling the collaborative editing and sharing of process models [5]. Process modelling tools nowadays offer a rich set of features for presenting, editing, analysing and sharing business process models at different levels of detail [6] and to support key activities across all phases of the business process management lifecycle – starting with the discovery of "as is" processes [7] up to the deployment of "to be" process models and their use by a range of users involved in the daily execution and management of these processes [8].

In general, the first goal of a business process model is to give an understandable and relatively unambiguous view of the elements composing a process (e.g. activities, events, data objects) and their relationships [9]. Given this goal, it seems natural that diagrammatic notations play a significant role. Diagrams are a natural fit when it comes to capturing relations in a way that is widely understandable, compared to free-text [10]. Practice also shows that the readers can grasp important elements and their relations faster with diagrammatic notations compared to free-text [11]. More broadly, diagrams have been shown to offer an effective way to transfer knowledge in organizational settings, well beyond the field of business process modelling [12].

However, diagrammatic notations are not the only, nor the primary way of storing and transferring organizational knowledge in general [13] and process-related knowledge does not escape to this rule. For example, it is common for knowledge of organizational policies and procedures to be captured in textual documents. Regulatory documents, which typically guide much of the processes in public organizations, are also generally captured as text. Many of these documents constitute *textual process models*. The use of the term "model" here is justified since, despite consisting of free-text, these documents capture information about the performance of a process at different levels of abstraction in a way that supports the understanding and analysis of the process. In many cases, these textual process models are very widely used on a daily basis. For example, it is common for debates about how to handle certain process instances to be settled by referring to articles or paragraphs in a (textual) manual of policies and procedures. Novice workers might even consult such manuals on a constant basis in order to resolve their doubts.

The above discussion raises the question of how diagrammatic and textual representations of process models co-exist in modern organizations, and how this co-existence influences the daily use of process models. These two questions constitute the setting of this thesis.

1.1 Problem Statement

There is a well-established body of knowledge in the field of Business Process Management (BPM) pertaining to methods, techniques and tools to discover, analyse, redesign, implement and monitor of business processes – the so-called *BPM lifecycle* [14]. On the other hand, the introduction and actual use of business process models in organization has been studied to a significantly lesser extent [15]. Little is known regarding the question of how business process models blend into the knowledge base [13] of an organization and in particular, how business process models are used different purposes by different user groups in the long-run.

Considering the use of process models in time, we can typically see very different usage patterns depending on the stage of the BPM lifecycle [14]. In the first stage of the BPM lifecycle (process discovery), the modeller captures facts concerning one or more business processes, which they perceive to be important for their intended purpose(s). The types of facts captured in the process model (e.g. activities, data, actors and their relationships), the clarity of the structure of diagrams for the presentation of information, the correctness of the captured information (reflection of real life facts) [16] depend directly on the modeller. For the modeller, the process model represents a structure on the basis of which important facts are described with a certain level of accuracy and detail, taking into consideration the purpose(s) for which the process model is created.

In the stages of process analysis and redesign, the users of the model are analysts whose aim is to find possibilities for redesigning a current process (As-Is) in order to improve its performance with respect to certain performance objectives. As part of their redesign effort, analysts typically produce a new process model (To-Be), which they use to communicate with other stakeholders involved in the redesign effort (e.g. other analysts, managers, IT developers). This redesign effort is usually done in the context of a well-delimited project. The use of the process model by the managers and process workers may continue also after the project, for example to monitor the performance of the to-be process past its implementation and to fine-tune it based on the insights gained via monitoring.

Process models produced in the context of a given project are created with a certain purpose in mind and may or may not be suitable for achieving other objectives. For example, some process models are created to provide detailed requirements for IT systems development. Such diagrams are typically too detailed to be used as an ongoing knowledge source by process managers or workers [17]. The same may hold true for models designed for quantitative process analysis (e.g. simulation) [18]. These detailed process models might still be reused (e.g. by analysts or IT developers) in a subsequent project concerning the same process, but they are unlikely to be used by process workers on a regular and long-term basis as a source of knowledge to execute instances of the process.

This thesis is concerned with the overarching question of what determines that a process model created during a process documentation or improvement project will be used on a *sustained* basis. Sustained use of a process model is herein defined as use by a wide range of stakeholders (not only managers and analysts, but also process workers), on a regular basis (daily or weekly), for a long period of time (at least one year) after initial creation of the process model. In other words, sustained use goes beyond the classical notion of *process model reuse*, which might occur for example when a process model is reused in a different project and on a regular basis.

In this setting, the overarching research question of the thesis is: "What factors affect the sustained use of process models in an organization?" Within the scope of this overarching research question, the thesis specifically investigates the hypothesis that sustained use is driven by two categories of factors:

- Factors related to the organizational setting in which a process model is produced and used, and quality attributes associated to the process model itself.
- The format in which the process model is presented, specifically the degree to which the process model combines structured components (diagrams and tables) with unstructured (free-text) components.

Accordingly, the above overarching question is approached by means of three complementary studies addressing respectively the following questions:

- How do diagrammatic, tabular and textual representations of process models co-exist in organizations and how can organizations map their collections of process models across representation formats and levels of granularity?
- What factors related to the organizational setting in which process models and produced and consumed, and what attributes of the model itself determine whether or not a process model are used in a sustained manner?
- To what extent and in what way does the format of process models (diagrammatic versus text) affects their sustained use?

1.2 Methodology

To address the first two research questions, we adopted a design science method [19] to design an initial artefact, followed by a multi-case-study method to validate and refine the designed artefact [20]. In the first study, the designed artefact is process documentation assessment model, and in the second study, it is a factor model. In both cases, the method followed is the following:

- First, and in line with the accepted recommendations in the field of design science in information systems, we carried out a literature review with the aim to concentrate the results of similar studies, and to find out frameworks and models that have been previously used to address the question at hand.
- Second, we defined an initial artefact by synthesizing the results of the review of existing work, and organizing it into separate dimensions (in the case of the first study) or separate groups (in the case of the second study).
- Third, we tested the framework in different types of organizations using a multi-case study approach, with the aim to see how systematised view supports the understanding of the organization as a whole and how it helps to bring out the bottlenecks and possible further directions.
- Finally, we improved the initially designed artefact on the basis of feedback received from the case studies, highlighting especially how ideas could be found concerning the wider use of the process model in the organization, building on the framework.
- After the study was completed, we tested the framework by re-applying the refined artefact in the same organizations several years later (in the case of the first study), and by applying the artefact in additional organizations (in the case of the second study).

In the third study, corresponding to the third research question above, we applied classical exploratory analysis [21] where we defined an initial set of hypotheses by analysing the research question, and identified variables and scales that could serve to test these hypotheses. We then collected the values of variables from one organization, cleaned the data and carried out logistic regression analysis. We interpreted links with a strong correlation and compared our findings with findings in related studies.

1.3 Scope and Limitations

All three studies reported in this thesis focus on conceptual process models [14], that is, process models designed for communication and documentation in an organization. The process models developed for business process automation (for example, models intended to be deployed in a Business Process Management System [22] or detailed specifications written purely for software development teams [23]), are not included within the scope of the studies.

Additionally, the three studies analyse purely the "use" of models. Related aspects are not included in the research such as the impact of process models to the organization [24]; their direct and indirect value [25]; and efforts related to the model maintenance [14].

Finally, the three studies focus on the use of the process model itself, leaving aside the use of related artifacts used in conjunction with process models (for example, enterprise architecture models or data models).

The findings of the three studies should be construed in the light of typical limitations and threats to validity of case study research. A key threat to internal validity of the studies is that the number of models and organizations was relatively limited. On the other hand, the set of organizations involved in the case studies is rather diverse, covering both the public and private sector, different business sectors, and different sizes and levels of process modelling experience.

An important limitation of the case studies results from the fact that the studies have been conducted in one single country – analysis and assessment methods offered in the study have not been tested in various cultural and economic contexts. This must certainly be taken into account when offered methods are used or generalisations applied in another country having a significantly different economic or cultural context. Implementation of the studies in different countries in the future would give an international dimension to the results, and would help to take into account differences in culture and differences in the markets and regulations in which the organizations operate.

There is an important limitation concerning the two first studies (Chapters 3 and Chapter 4), namely that these are of an exploratory nature and the observations made in them lack any statistical significance. There are quantitative data and analysis involved in the third study described in Chapter 5, but the research is restricted to a single organization. A direction for future work is to conduct further quantitative studies in order to refine the observations made, particularly in the first two studies.

1.4 Contributions

In the first study, we designed a framework – namely the Process Documentation Cube (PDC) – for mapping an organization's process documentation. The idea of implementing a structure for presenting a general structure of the documentation of the organization (knowledge base) came from the daily practice – most organizations do not have a visual representation of the general structure of their knowledge base and a common understanding about the documentation is lacking. Process Documentation Cube proposes a simple structure for systematising documentation via three structured views, which are easy to understand for people who already have basic knowledge on process models. First, we applied the structure in six organizations to validate the hypothesis that the PDC provides an effective overview of process models both to internal and external stakeholders, and that it can be used as a basis to establish a roadmap for future process model documentation. This first study was initially documented in the paper “The Process Documentation Cube: A Model for Process Documentation Assessment” [26]. In this thesis, we have extended the research reported in the latter article with further case studies (all together about 10 organizations) and a longitudinal evaluation of the PDC across multiple years in the same organizations where we had initially applied it.

The focus of the second study is on factors pertaining to the production and consumption of process models in an organization, which can affect the sustained use of process model. First, we carried out a literature review and identified success factor models in the areas related to process modelling and process model use. Based on the review, we compiled an instrument to assess how an organization manages process model production and use. The assessment instrument is based on a set of factors of process model production and use and a set of so-called “activities” that can improve the management of process models with respect to these factors. We tested the assessment instrument in four different types of organizations and gathered feedback on the perceived importance of the proposed factors for sustained process model use. Consecutive case studies (seven organizations) supplemented knowledge from various experts and gave feedback on assessment implementation. This feedback was used to refine the initial assessment instrument. The second study is reported in articles “Towards an assessment model for balancing process model production and use” [27] and “Factors Affecting the Sustained Use of Process Models” [28].

The third study investigates the links between process model structure (as defined in the first study) and sustained process model use. We formulated four hypotheses concerning the process model structure and defined variables to measure important aspects of the process model structure and the sustained use of the process model. After preparations for the study were made, we found a suitable organization for the study – mature in business process management area, having various process models in daily use. Based on the study preparation, the data concerning variables was collected, cleaned and analysed. The analysis highlighted a couple of relatively strong correlations between the independent variables reflecting the structure of the process model and the sustained use of the process model (dependent variable). The outcome of this study is a set of recommendations to achieve a suitable balance between diagrammatic and textual components in a process model. The third study is reported in the paper “On the Effect of Mixing Text and Diagrams on Business Process Model Use” [29].

Third study (referred to in Chapter 5) and ranking of factors drawing on expert knowledge (referred to in Chapter 4) can be viewed as additions to offered frameworks in order to improve their substantial correctness and usability in practice.

The frameworks designed in the studies and the feedback obtained from their application collectively provide insights into how organizations can map and assess their existing process documentation and their process modelling projects in order to enable sustained process model use.

Altogether, 18 organizations were involved in the case studies reported in the thesis. Table 1 provides an overview of the organizations and their participation in each study (1 – Process Documentation Cube; 2 – Process Model Production and Use; 3 – Factors of Sustained Process Model Use; 4 – Mixing Text and Diagrams).

Table 1: List of organizations attended in the studies

Organizations	1	2	3	4	Private	Public	Web-page
Ministry of Interior – IT department	X					X	smit.ee
City Council of Tartu	X					X	tartu.ee
Labour Inspectorate	X	X				X	ti.ee
SEB Pank (Bank)	X				X		seb.ee
Unemployment Insurance Fund	X					X	tootukassa.ee
Tax and Customs Board	X	X				X	emta.ee
Estonian Public Broadcasting		X	X			X	err.ee
University of Tartu		X				X	ut.ee
Estonian Energy		X	X		X		energia.ee
Elisa Eesti (Telecom)		X	X		X		elisa.ee
Rescue Center	X	X	X			X	rescue.ee
Estonian Agricultural Registers and Information Board	X	X	X			X	pria.ee
Social Insurance Board			X			X	sotsiaalkindlustusamet.ee
E-Health			X			X	e-tervis.ee
Telia Eesti (Telecom)	X		X	X	X		telia.ee
Saku Metall (Industry)			X		X		sakumetall.ee
Veterinary and Food Board	X		X			X	vet.agri.ee
Bank of Estonia			X			X	eestipank.ee

1.5 Outline of the thesis

The thesis is organized as follows. Chapter 2 presents a review of the state of the art in the field of process modelling, process model quality, process model use and impact, and the related field of knowledge management where the question of sustained use of organizational documentation has been widely studied.

The subsequent three chapters (3–5) describe the three core studies of the thesis, which are summarised on Figure 1.

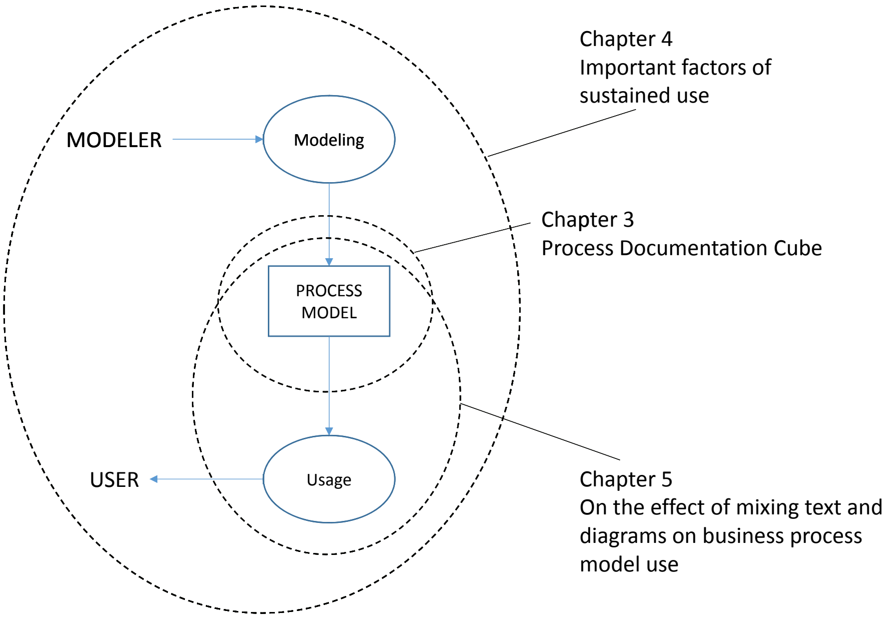

Figure 1: General context of studies covered in the thesis

Chapter 3 deals with how to map the process documentation of an organization holistically via the so-called Process Documentation Cube [26]. This chapter can be seen as dealing with the "process model" itself, independently of its production and use.

Chapter 4 focuses the production of process models, and specifically, which factors pertaining to the production of a process model have an influence on its subsequent sustained use. The chapter thus looks into the creation (or "discovery") phase of the BPM lifecycle [30], the introduction of the process model into the organization [12], and some elements pertaining to the ongoing management of the process model [31].

Chapter 5 studies the links between parameters that characterize the format of process models – particularly their diagrammatic versus textual nature – and the sustained use of process models in an organization.

Finally, Chapter 6 closes the thesis with a summary of the contributions and a discussion of limitations and directions for future work.

2. STATE OF THE ART

For the process model to become used in an organization on a daily basis as part of the knowledge base [13], usually many steps are taken: creation and analysis of the process model, changing the model, use of the model in the context of a project, integration of the process model into the knowledge base, update of the knowledge base. In the course of these steps, on one hand, the process model is supplemented, on the other hand, in most cases, changes occur also in the organization: processes are modified on the basis of the changes made in the model, software is introduced, employees are trained, etc. Even if the project including processes is not directed at the sustained use of the model to be created in the course of project, it still has an indirect impact on the organization's knowledge base and the users – in the course of the work, existing documentation changes, and employees are trained directly or indirectly. In the following, we have observed which research areas are linked to different steps, from which angle these different topics have been handled and how this ties in with the studies carried out within the thesis.

2.1 Process model(ing)

2.1.1 What is process model and modelling?

A process model is "an abstract representation of an organization, be it conceptual, textual, and/or graphical, of all core interrelated architectural, co-operational, and financial arrangements designed and developed by an organization presently and in the future, as well as all core products and/or services the organization offers, or will offer, based on these arrangements that are needed to achieve its strategic goals and objectives [32]". Creation of such a model, in other words, describing an organization in important detail is called modelling. The definition offered by Al-Debei, El-Haddadeh and Avison brings out the object described in modelling, which comprises the products or services of the organization that are necessary for the achievement of the organization's objectives. The definition also demonstrates the technical means used in modelling on the basis of which the model is compiled – conceptual, textual, and/or graphical. Thus, in (process) modelling two skills are required: the skill to highlight important facts and links related to the achievement of the organization's important objectives, on one hand, and the skill to describe those facts and links through different means – text, tables, figures – on the other hand.

In organizations, numerous descriptions occur in the form of texts: work instructions, job descriptions, description of the organization. The advantage of the description in the form of text is that everyone can read and, as concerns short descriptions, the reader is able to grasp the text as a whole. At the same time, text poses a problem in describing a larger and more complex system as describing different facts and links by means of text only [33] is difficult and for the reader to understand these facts and links is even more complicated [11]. In order to simplify describing complex systems, already in the previous century notations were created to show how to present different facts and links graphically – the Gantt Chart [1]. One of the first notations created for describing large systems in the context of programming was the Structured Analysis and Design Technique [4] proposed by Douglas T. Ross in the 1960s. Notation arose from the context of software development where the functionality of the system needed to be described and analysed in detail in the creation of the system before its realisation. The proposed notation gave a visual tool for depicting complex workflows and dataflows, applying hierarchical decomposition [34]. Later, this resulted in IDEF notation [35] which, in addition to the presentation of the activities of the system (IDEF0), also included the graphical representation of data (IDEF1) and the possibility to represent the dynamics of the system (IDEF2). To date, a more general and universal notation of the modelling of activities, Business Process Model and Notation (BPMN) [36] has arisen from different notations of process descriptions. In addition to software development, it is also used for describing and analysing an organization from the business view: quality management [37], business management [38], process improvement [39]. The abundant selection of graphic elements of BPMN offers a wide opportunity to depict different facts and links on a diagram; due to this, the notation suits many different purposes, if one wishes to communicate important facts related to the activities of the organization. BPMN is integrated into modern tools of software modelling (UML [40]), the notation is used in tools directed at the analysis of an organization [36], reference models of many fields have been compiled by means of BPMN notation (eTOM [41], HL7 [42]).

Today, modelling cannot be considered as a separate entity from the software that supports the creation of the model (modelling) as well as the analysis and management of the model. Also, the process is an input for different applications which support the analysis, operational management and monitoring of processes in an organization (Process Simulation [43], Work Flow Management [44], Data Flow Management [45]). Moving along the stages of a BPM lifecycle, software supports the creation of diagrams – tools starting from the simple ones for compiling diagrams (Visio, Bizagi Modeler) to more complex systems (Signavio, ARIS) offering additional functionalities for the management of a process model as a whole in addition to the diagram activity itself (quality inquiries on the basis of a repository [46], quality control of the diagrams, tools for process analysis, etc.) are in use. Thus, additional functionalities and support for different stages of BPM lifecycle can be found:

- Process Discovery [47] process model generation on the basis of the organization's operational database.
- Simulation of processes [43] in the analysis stage, enabling to simulate real situations on the basis of a modelled process model, and helpful in complex systems where the result of process(es) execution is not predictable; for

example, the frequency of process execution is high, and thus the number of entities of the process in real life is big.
- Different outcomes and reports which systematize the entered facts in different formats: activities concentrated by the actors (work instruction), use of data by different actors (matrix of the rights of use of data).
- Conformance Checking [48] – at the update of the model during the later management of the model in order to highlight the moments of splits between the theoretical model and real processes.

Dealing with processes may be limited to the compilation of a couple of texts and diagrams for providing an overview of a small amount of objects and important links between them. Also, the project of describing the system may last for months, resulting in a detailed description of a large-scale system where different methods for improving and changing the process model are applied. In accordance of the aim (that will be covered in more detail in Chapter 2.1.2), a notation and tool (software) suitable for modelling must be chosen as well as necessary methods to be applied on the created model.

In my thesis, primarily those models describing activities have been examined which have been created in the organization at different times and for different purposes. In our studies, we have not narrowed the model with a specific notation or a tool – different activity models in an organization, which have been created by means of different tools, notations and methodologies have been observed.

2.1.2 Why process model(ling)?

In describing processes, a process model is formed which describes the important facts of the organization; model is of help in understanding and analysing important objects and links of the organization. In the following, we have examined the situations and purposes for which such description of an organization can be used in practice.

Process model as records

Process modelling may be limited only to describing the processes – activities and related important objects (data, actors) are described, bringing out important links (sequence of activities, use of data at the activity, the performer of the activity) [14]. Such description may be used in different contexts where the information presented in the description must be communicated: induction course for the new employee, operational coordination with a business partner (combining the processes), employee looking for an answer to a question arisen in the course of daily work. In summary, this is a description that reflects the knowledge concerning the organization; by a process model, such knowledge has been systematised by activities. The aim of such knowledge base (Chapter 2.3.2) is primarily the concentration and recording of important knowledge concerning the organization on one hand, on the other hand, also sharing this knowledge, which results in ensuring the coordinated management of and communication in the organization [49].

Process model for changing the organization

In most cases, a business process modelling project is triggered by the need to improve the organization, to change the service or product, preceded by describing the system. Here, it must be defined which aspects are requested to be changed and what is the balance requested to achieve as regards different aspects [50]. Looking at the organization as a whole, it is vital to analyse in carrying out such changes how those changes will affect the whole, and if the planned changes are (at least theoretically) sensible – having a desired balance as regards the important aspects. For example, if the quality of a service or a product should be improved, activities related to quality control can be planned in the process model. At the same time, it must be kept in mind that adding activities may result in a longer process (additional time spent), and in most cases, the cost of a service or a product will increase.

Upon changing processes on the basis of a model, usually two models are used – a model describing the current situation (As-Is) of the one part and model reflecting the changes (To-Be) of the other. As-Is model is used for detecting the bottlenecks and problems in the system, the purpose of To-Be model is testing the change(s) on a theoretical model. The comparison of two models provides a theoretical assessment on the usefulness of the changes made and their influences in the organization, which enables to assess the changes before introducing them in the organization.

Qualitative analysis

By qualitative methods [51], the process analysis takes place via observation, in the course of which bottlenecks and defects of the processes are identified. The basis for qualitative analysis is an assessment on the process by a specialist or analyst – on the basis of observing the facts and parameters related to the process, an assessment is given and proposals for changes in the process are made.

The most common example of qualitative analysis is the organization's employees' assessment on the process – employees' opinion on the current process (list of problems) and recommendations for changes on the basis of this (list of proposals) [14]. The employee knows the processes he/she participates in, and, on the basis of everyday experience, can point out problems and make proposals concerning the improvement of (an aspect of) the process.

The second example could be the analysis that started with the car manufacturer Toyota and, to date, has been integrated into many methodologies – Waste Elimination (LEAN) [52]. In the course of the analysis, one moves along the steps (activities) of the process, evaluating whether the specific activity helps to achieve the objective of the process or not. Such step-by-step assessment of the process helps to bring out those activities which benefit little the achievement of objectives and the elimination or simplification of which would not change the result of the process as a whole, but, at the same time, shortens the process – time and resources spent on the process. Lean method has been rooted in different improvement methodologies, which enable to analyse activities in the way described above.

Similarly to the Lean methodology, structure of activities also provides a basis for the Root Cause Analysis [14] – activities where the problem(s) occurred are highlighted on the process model and the movement begins along the process chain in the direction of the beginning of the process in order to find the reasons which caused the problem. Usually, causes of the problem are hidden before the problem becomes known; thus, process description that brings out the sequence of activities (time axis) comprises a structure for moving from the activity where the problem was identified towards the activity (in temporal terms, towards the beginning of the process) where the problem essentially started.

Pareto Analysis [53], in the course of which an assessment is given to the impact of identified problems can be applied additionally by means of methods described above for analysing and systematising the problems indentified. Typically, four attributes – performance, cost, risk and quality – are used in the assessment of problems. Those attributes are given an expert assessment in order to highlight and rank the importance and influence of the problems in the organization. Such assessment is important before the introduction of changes, as in practice 20% of issues are responsible for 80% of the effect – if we start with the more influential problems in the change-making process, the relation of the result of the introduction is bigger especially during the first steps of making the changes. Following those numbers that reflect the percentages, this approach has also been titled as the 80–20 principle.

Quantitative analysis

Quantitative methods [54] are used to measure the system parameters and (unlike the assessments given in the qualitative analysis) the values of parameters are calculated in the system of the moment (on the As-Is model), and the process is attempted to change in a way that the parameters could give the desired result (balance) on the changed model (To-Be). The most typical parameters in the process analysis are time, cost and quality; new significant measurements such as flexibility or risk can be defined, where necessary, but the measuring and accuracy of these may prove as complicated and insufficient for correct calculations.

Flow analysis enables to calculate the average value of the parameters of the series of elements if the value of each element and the logic of the sequence of the series of elements are known [45]. Thus, we can, for example, calculate the average duration of the process (Cycle time – average time spent for carrying out the activities of the process), knowing the average time spent on each activity and the probability of the events of the process diagram, or, in a similar manner, to present the average cost price of the process, knowing the cost price of each activity of the process and the probabilities of events.

If multiple copies of one process (entities) are launched in real life and activity-related resources are scarce, it could be useful to apply the Queueing Theory [55] in the context of the parameter of time. The aim of this theory is to calculate the sections of the process where delays or bottlenecks occur in connection with limited resources during the process implementation. In practice, service processes where the number of copies varies in time provide an example – for instance, within the service process of a shop, each customer launches a new entity of the process. In case of the example of a shop, it is important to know how many service workers should be employed at the peak time in order to serve the customers without creating long queues. In order to do the calculation, the parameters characterising the frequency of launching the process must be known as well.

Improving an (or many) aspect(s)

In the modification of processes [56], it must be taken into account that the process is characterised by different parameters, and changing one parameter in a positive direction (from the viewpoint of the context of the organization's objectives) may exert a negative influence on other parameters. For instance, improving the quality of the result of the process (service or product) may lead to the increase in the cost price of the service or product; adding supplementary equipment or activities for improving the quality results in additional expenses. It must also be considered that a certain period of time exists for covering an investment accompanying a number of changes; during that period, benefit accruing from the change covers the investment (Return-On-Investment) [57]. For example, information technology is used in order to speed up data management and facilitate communication, at the same time, the investment related to the purchase and introduction of the information system as well as the following administrative costs are quite high, subsequently, the pay-back period of the investment may be quite long [58].

In order to find the balance between the parameters that characterise the organization, the method of Balanced Scorecards [59] has been used in practice – as the name of the method refers, it consists of balancing different parameters according to the objectives of the organization. Parameters largely depend on the organization, but parameters related to money and business measures reflected primarily in time and quality are typically observed here. Depending on the field, topics related to customers, risks, innovation and other important indicators may also be critical.

Process model as the software input (Process Automation)

To continue the topic of quantitative process analysis, our first example (Chapter 2.1.2.) is the case where in a process model, simulation is used as input in a software application [60]. A process simulator generates a large number of hypothetical entities of a process on the base of the process model, executes these instances step-by-step, and records each step in this execution. By means of simulation, situations happening in the performance of processes in real life can be “played” and thus the weak points that occur in a specific context – peak time, overload, failures – can be spotted. The functionality of the process simulator has been integrated in different modelling tools – ARIS, Signavio, Oracle BPA.

In addition to the use of a process model in the analysis stage, the process model may be used as input in the performance of a real process – as the process defines the sequence of activities and the progression of the process flow between different participants in the process, it may be used as input in information systems that support complex processes and manage the communication of these processes – work flows. Best known applications for Workflow Management Systems (WfMS) [61] the purpose of which is the coordination of a process on the basis of a given process model, are IBM Lotus (Workflow) and YAWL. The functionality of WfMS has been integrated in many information systems [22] which support the performance of complex processes in an organization.

The third example could be functionality that is oriented towards the process model in later stages of its life cycle – functionality Conformance Checking [48] supporting the update of the process model. In conformance checking, the theoretical process model is compared to the process course in real life reflected by database entries in the information system. The aim of such comparison is to find process scenarios that are not reflected in a theoretical process model. Thus, a discrepancy between practice and a theoretical model can be found: a step is skipped in the execution of the process, or activities are carried out in another order as on the theoretical process model. Such discrepancies can be of critical importance from the angle of the quality of a process as a whole; also, it may refer to an improvement proposal that has been already introduced without consulting.

In this thesis, we have observed process models directed at the employees (process workers) for understanding important details of the process and for additional information. In this use of a model, ease and speed of finding the facts is important. The employee usually uses the amount of information for specifying the nuances of single processes or for understanding the wider context (how the specific process ties in with other processes). Process models created with the aim of applying quantitative analysis methods or designing IT-solutions are usually too detailed and complicated (technical) from the viewpoint of a regular user. In our studies, we have researched the models from the angle of how to make such models usable for the employees of an organization. The given studies emphasize important points on what should catch our attention if the focus of the model is its sustained use in an organization.

2.1.3 Process modelling methodologies

In this chapter, we have brought out the most widespread methodologies which assemble technical expertise and experience, and highlighted how to compile, use and, in the long term, manage models. Such methodologies may be divided into three [5] parts according to their purpose and viewpoint of the organization:

- **Business Management view**, with a purpose of managing the whole and lead the organization. The organization is viewed top-down and the aim of the model is to grasp and systematise the whole.
- **Business (specialist) view**, with a purpose of simplifying and improving processes. Daily processes of the organization are observed through which services are provided, goods produced and support services provided for the main processes.
- **Technical view** of the organization the result of which is the attempt to make the organization more efficient through the application of technologies. As this view deals with the automatization of activities, modelling must be done very precisely before "the jobs are taken from the people" so that after technologies have been applied, the end result would be better – cheaper, faster, of higher quality.

Manager's view of the organization
At the manager's view, it is important to grasp the organization as a whole at a general level with the aim of using the obtained knowledge for managing the organization. In the process view, it is important to highlight general activity groups and the links between them by such methods and models.

In the year 1985 Porters introduces the concept of Value Chain [62] in the management level view, through which a structured and integral view at the organization is presented – dividing the organization into important subdivisions and the specification of those links. Years later 1996 a Supply Chain Council (SCC) creates a general framework SCOR, on the basis of which a complete supply chain architecture of the organization is to be created. SCOR framework divides the organization into six areas from the management view: plan, source, make, deliver, return, enable. In the context of process models, the proposed approach ties in with process hierarchy [34] – how to decompose the organization into subdivisions, following the business logic of the field.

A more detailed view at the organization the aim of which is (in addition to management) performance improvement, is presented by Rummler and Brache [63]; in addition to the management of the organization as a whole, all important topics on the management level are covered: purposes, indicators, records, management.

In addition to the manager's view structure, 1995 Kaplan and Norton proposed in 1995 a meters' system Balanced Scorecards [59] for strategic planning and management. Balance Scorecards brings out four important perspectives, through which the organization can be viewed and indicators defined (Key Performance Indicator): Learning and Growth perspective, Business process perspective, Customer perspective, Financial perspective. Balanced Scorecards demonstrates how to develop metrics on different management levels of the organization, to gather information operatively and to use it in the management context. The framework shows how to apply the method on different management levels and finally integrate them into one entirety [64].

A general view at the organization, but already in the context of a specific domain, is brought out by different reference models [65]. As the process logic of similar domains (at least on a general level) is similar, the general structured view has been concentrated into a separate model that provides a basis in creating and improving the organization's process model – the process hierarchy that has been developed in the domain and proved in practice significantly facilitates the creation of a process model both as regards the general technical view as well as business view. Thus, domain models have been proposed in health (HL7 [42]), IT-management (ITIL [66] , Telecom (eTOM [41]). If a reference model is taken as a basis in the creation of the process model, it significantly saves the time spent on the creation of the model, and improves the quality of the model as a whole especially from the usability aspect.

In summary, the focus of management methodologies is on the upper levels of process hierarchy and they bring out recommendations on how to manage the organization as a complete whole.

Business view

In comparison with the management view, methodologies connected to the business view are concentrated on the next (lower) levels where the focus of methodologies is on the improvement of activities which are directly linked to services and production, and this leads to a better result as a whole. In addition to improvement techniques and tips, these methodologies also include important facts and techniques related to the introduction of the change.

Bill Smith proposed, on the basis of Motorola experience, in 1986 a set of techniques and tools for process improvements grouped under the term Six Sigma [67]. As the name of the methodology indicates – quality is expected of the process, where 99.99966% of the result meets the quality requirements (3,4 failures during million performances). The approach which arose from the industry and to date has been introduced in many enterprises brings the constant improvement of daily processes and improving the quality in the centre of attention. Six Sigma looks at processes from the quality aspect and emphasizes important moments how to achieve the smallest number of defects possible as the result of the process. Number of defects is also the indicator on the basis of which the organizations introducing Six Sigma are divided on seven levels following the process result.

Similarly, Lean methodology [52] is focused on the improvement of the process. Elimination of irrelevant activities which do not add any value (elimination of waste) is in the centre of this methodology. Like Six Sigma, Lean technique arose from the (car) industry – Toyota. Lean methodology does not only include technical mechanisms of process improvement; strong emphasis is placed on the introduction of methodology in the organization, especially on changing people's attitudes.

BPTrends Process Redesign Methodology [68] concentrates the knowledge of how to change processes in the organization, highlighting the activities step by step that need to be carried out when dealing with processes. BPTrends

Process Redesign Methodology connects the technical side of dealing with processes (creation, analysis, management of the process model) and the commercial side (how to connect the theoretical model with the practical side in different stages).

Technical (detail) view

Unlike the manager's and business view, modelling methodologies linked to the introduction of technologies are focused on details – the domain that needs to automatized is identified and described in detail [69]. In order to automatize activities or data management, the system must be modelled on a detailed level and the use of technology planned on a detailed level, and changes in processes occur as a result. We have brought out the methodologies that are linked to information technology projects.

The backbone of software design [23]is indirectly linked to the paradigm of the programming language: in the end of the last century, languages of structural programming (C, Basic, Pascal) were used; turn of the century brought the object-oriented approach (C++, Java). In the centre of description (modelling) that preceded programming in the 1960s was primarily the modelling of data and their use which is summarised by Yourdon [4] in his book as an integral methodology (structured analysis). Data-centred view was the result of the approach to software as a tool for simplifying and automatizing data management. A similar set of diagrams directed at structural programming concentrates IDEF0 Methodology [35] and guidelines for composing software records on that basis.

Rapid development in the following years brought along a change in programming paradigms (from the structural approach to the object-oriented approach [70]), which, in the context of software documentation resulted in the need for detailed descriptions of objects. Unified Modelling Language (UML) [40] became the standard of the documentation of software design and one of the best-known development methodologies was the Unified Software Development Process [71], proposed by the company Rational. Looking at different software design documentation notations in time, reflecting the activities and processes of an organization has been quite similar – the use of Workflow diagram and IDEF0 notation years ago, from where the widespread BPMN notation [36] has developed by today, offering more possibilities for describing business processes.

Within our studies, models with various purposes and for different user groups have been observed, which are directed (can be directed) at employees for using as documentation on the process. Studies referred to in the thesis bring out moments that are important if process models are to be used in sustained manner in the organization.

2.2 Process model quality

The central object in the context of BPM life cycle is the process model – it comprises an outcome and input of different stages of the BPM life cycle. Due to this, the result of different activities starts with the process model and, in many cases, this result depends directly on the quality of the process model [72] – better quality of the model gives, for instance, a more accurate and correct result in process analysis. As the purposes for the use of process models listed in Chapter 2.1.2. differ from each other, quality requirements for a process model are similarly different in the achievement of those different purposes. In this chapter, we have considered how to measure and assess the quality of a process model and what can be done to improve its quality. In this chapter we highlight different aspects related with the process model quality.

2.2.1 Dimensions of process model quality

Many different people participate in the creation of a process model (the modeller, process workers, analyst); also, different information sources are used for gathering the facts (documents and models describing the organization, reports and presentations, information and experience from other areas), and all these together influence the process modelling and the quality of the model which is formed [72]. This quality is important primarily for the users of the model to be created.

Framework by Lindland [73] highlights important aspects on the basis of which quality aspects for conceptual models can be defined (Figure 2).

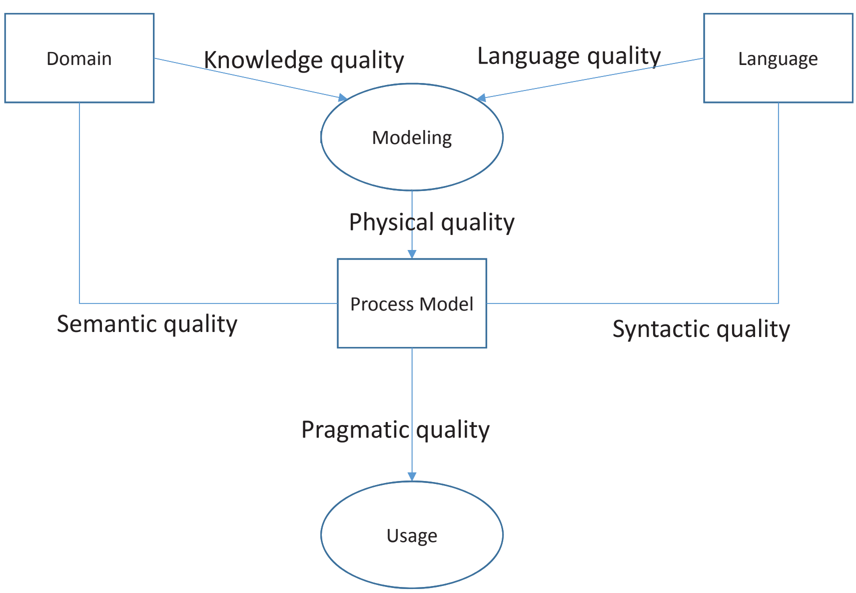

Figure 2: Lindland framework about the quality aspects for conceptual models

Looking at the process model from the angle of modelling, the first important thing is the reflection of the content of the processes in the process model, and to what extent do the facts described in the model correspond to the actual system (domain) that has been modelled – **knowledge quality** of the system. Inaccuracies and discrepancy begin from the original source of information (initial information may be inaccurate or become inaccurate in the course of information exchange). For improving knowledge quality, people who know the system may be chosen to be modelling input providers, also, same input may be collected from multiple persons in order to improve the quality. However, it must be kept in mind that too much information can make the input too complicated, which in turn increases the probability of mistakes by the modeller upon systematizing the information and transferring it into the model.

On the other hand, inaccuracies in facts in the model may occur in connection with the modelling language used – constraints of language do not enable to describe the system accurately enough or in a sufficiently correct manner – **language quality**. Here, using a suitable language (notation) and tool is important; this enables to systematise and record the gathered knowledge in writing in a form that takes into account the purposes of the further use of the model.

Knowledge quality and Language quality create preconditions for creating a process model. At the same time, an important part in the quality of the model is played by the modeller who compiles the model on the basis of the above (**Physical quality)** – how well can the modeller reflect the facts describing the system in a chosen language in the process model. The first most important thing is that the system must be entirely (the facts reflect fully the whole modelled system) and correctly (language rules are adhered to and the facts have been correctly presented) modelled.

From the user's view, it is important that:

- the facts presented in the model reflect the real system (**Semantic quality**);
- the model has been compiled following the rules of the chosen notation (**Syntax quality**);
- process model is easy to use and intelligible for the user of the model (**Pragmatic quality**).

Content-wise, the **semantic quality** of the model is determined by the accordance of the statements presented in the model with the real system. For checking the semantic quality, the statements presented in the model must be compared to the real domain, which is difficult to do. In such checking, it must be assessed if all statements included in the model are correct and relevant to the problem (***Validity***); on the other hand, it must be assessed if the model contains all relevant statements on a process that would be correct (***Completeness***). For checking the Validity, checking the facts and links reflected in the model with the expert in the area is sufficient; assessing Completeness, however, is much more complicated because in many cases the input provider (and the later tester) cannot recognise the missing details in the model, which should reflect important nuances of the real system that (may) carry a significant meaning in the context of the whole.

In technical terms, it is important that rules and guidelines of the language used (notation) have been followed – this enables to understand the written content unambiguously later (**Syntactic quality**). Formal ***Verification*** of language rules can be performed without diveing deep in the content of the process just by checking "manually" if the rules and guidelines have been followed. Verification functionality is integrated in many applications of modelling software; it is performed automatically in the course of modelling or implemented separately on a complete model in the end stage of modelling.

If the user of the model is a person, correspondence between model and audience interpretation (**Pragmatic quality**) is important in addition to the above – whether the facts and links presented in the model easily are readable and accessible.

Frameworks which have been developed later involve new aspects and bring out important quality-related topics. For instance, the model SEQUAL (Semiotic Quality Framework) created by John Krogstie years later [74] is based on theories from the field of semiotics, which extends the model through physical, empirical and social aspects. Thus, we can find from the SEQUAL model (Figure 3), in addition to objects within the Lindland frameworks ((Modelling) Domain, Language, (Process) Model) the following objects:

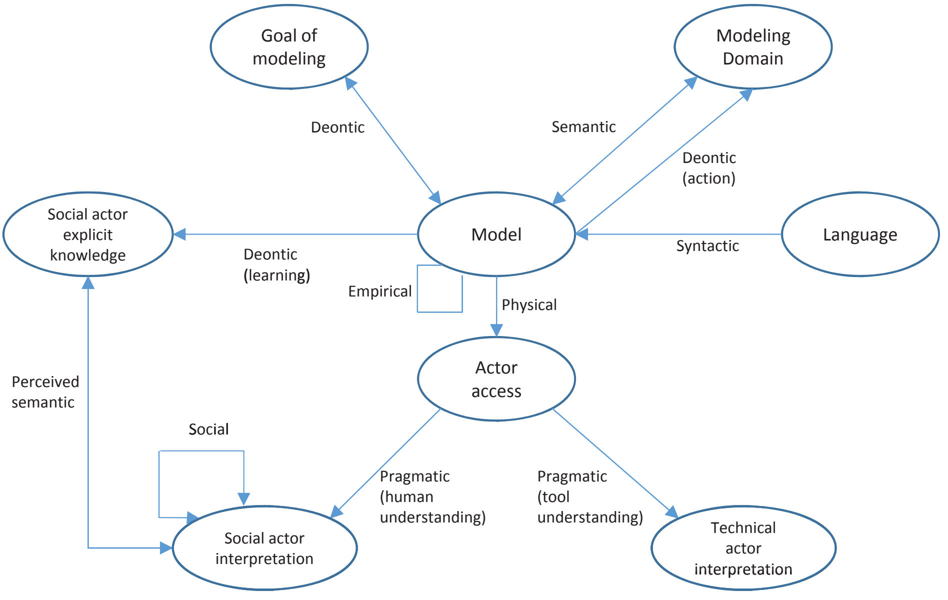

Figure 3: SEQUAL framework

- **Goal of modelling** – the aim of modelling is covered as a separate topic in the model.
- **Actor access** – user's (Social actors) access to the relevant parts of the model.
- **Technical actor interpretation** – technical support in the use (interpretation) of the model.
- **Social actor interpretation** – immediate substantive interpretation of the model.
- **Social actor explicit knowledge** – users (Social actor) explicit knowledge about the domain.

The main quality types have been highlighted on the links between these objects. In addition to the previously covered quality types (Syntactic quality, Semantic quality), we can find the following from the SEQUAL model:

- **Physical quality** – it is assessed whether the relevant parts of the model are available to the relevant users (Actors) and in which information is provided to the user (different versions, relevant meta-data).
- **Empirical quality** – addresses comprehensibility of the model for the relevant users (Actors).
- **Pragmatic (human understanding) quality** – it is assessed to what extent the users (Social actor) understand the model.
- **Pragmatic (tool understanding) quality** – it is assessed how much the software supports the user (Social actor) in the interpretation of the model.
- **Perceived semantic quality** – correspondence between the users (Social actor) interpretation of the model and their current knowledge of the domain is assessed.
- **Social quality** – the users' agreement among the user's interpretations is assessed.
- **Deontic quality** brings out the impact of the model on different objects of the quality model. In the context of purpose, it is assessed how the model supports the achievement of set goals, on one hand, and how the goals of modelling are addressed through the model, on the other hand. Another object in terms of which the impact is assessed is the Social actor explicit knowledge – how much do the users learn(ed) through the use of the model. Third, it is assessed to which extent the organization (Modelling domain) has been influenced through the model by the users (Social actor)

Framework Guidelines of Modelling (GoM) proposed by Becker et al. [75] is focused on a process model and quality is viewed through the modelling prism. Important guidelines to be taken into account in the compilation of a process model have been concentrated under six general topics:

- **Correctness** – here, primarily syntax quality and semantic quality have been meant – the model describes correctly the area to be modelled and the description follows the notation rules of the language
- **Relevance** – only the necessary elements and links are added according to the purpose of the use of the model
- **Economic Efficiency** – it must be checked that the costs of creating the model do not exceed the revenue to be generated.
- **Clarity** – the model must be clearly described, using the correct means of the used language in the correct amount
- **Comparability** – models created by different means must be comparable.
- **Systematic Design** – different models must be connected and constantly managed.

Guidelines brought out in GoM framework should be kept in mind in modelling in order to provide the process model with the physical quality on one hand and on the other hand it supports the pragmatic quality in the user's view.

For measuring the quality of the process model, Vanderfeesten et al. [76] have proposed metrics with five parameters:

- **Coupling** – the number of interconnections among the process diagrams in the process model.
- **Cohesion** – the relationships of the elements within a process model.
- **Complexity** – the number of elements and relations in the process diagram.
- **Modularity** – the degree of modularization in the process model.
- **Size** – the number of elements in the process model.

As can be seen, the central position belongs to measurable technical parameters – the proposed metrics has been developed in the process discovery context in order to assess the quality and complexity of the automatically derived process.

In the thesis, we have not directly assessed the quality of process models, but rather observed different model parameters that reflect quality (e.g. in the analysis treated in Chapter 5, parameters representing the structure of the process model are directly linked to the Pragmatic quality). Also, the central variable (Process model sustained use) of this thesis is a composition of different quality types – each aspect of quality ultimately influences the use of the model by the users.

2.2.2 (Pragmatic) Guidelines of process models

In order to improve the (pragmatic) quality of the model, different recommendations and guidelines have been assembled from practice and covered in studies. Following these guidelines makes the model easier to comprehend and understand for the readers. Majority of these simple rules consists of recommendations for the modeller so that the model to be created could be easy to use. These guidelines and rules may be divided by content and application into five [77]: size, structure, components, layout and general guidelines.

Size

The size of a process diagram has been emphasized in very different studies and highlighted as the primary factor that impacts model understandability [78] [79]. Sánchez-González et al. in their study [80] propose the number of process model elements to be 31; larger models become difficult to read. The same study states that "A model with a total number of events below 7 is easy to understand [80]" – such simple diagrams are typically general explanatory schemes that are easy to grasp as a whole for the reader. Mendeling et al. [81] bring out a bit bigger number and solution: "Decompose the model if it has more than 50 elements" – decomposition [34] has been one of the main tools which enables to transform large systems into a more simple and understandable form through dissembling. In summary, the size of the process diagram can be commented as follows: "Use as few elements in the model as possible [81]".

Structure

Structurality helps the reader to find important facts more quickly and gives a visually complete picture of interlinked facts in a process model. Application of structural decomposition is reflected in the process hierarchy through which the user gets the context where the process diagram is located in a complete process model [82]. Process hierarchy serves as contents for the user in reading the process model.

On a process diagram, the sequence of activities (time axis) is highlighted and in order to bring it out more clearly, different recommendations have been given as regards parallel process chains. "In a well-structured model, splits and joins are properly nested such that each split has a corresponding join for the same type [83]" – one wholesome section is brought out from the process chain. Studies have demonstrated that gateways make a process diagram more difficult to read [81], for this reason "Structuring leads to more understandable models if it does not increase the number of gateways [84]".

In summary, it could be stated that "A decrease in degree of structuredness implies an increase in error probability [85]" and in order to avoid that, "Model as structured as possible [81]".

Components

In process diagrams, it must be brought out at which point the process begins and at which point it ends: "Use one start and one end event [81]"; it should be taken into account that reflecting too many process triggers and results on one diagram makes the understanding of the process more difficult: "Use no more than 2 start and 2 end events [86]" and especially as regards start events: "Use only one start event in a process or sub-process [87]". Three has been proposed as the maximum number: "Use no more than 3 inputs or outputs (inputs + outputs) per connector [86]".

In order to avoid excessive complexity, one should "Minimize the routing paths per gateways [81]". In using gateways, use of OR gateway has been highlighted separately: "Avoid OR routing elements [81]".

Layout

For a person to follow a process diagram in a habitual direction, one should "pick a direction of Sequence Flow, either left-to-right or top-to-bottom [88]". In placing the elements, "place related elements spatially close to each other [89]". If linked elements are placed side by side, formation of long connectors on the diagram is reduced [78].

Placement of arrows on a diagram is brought out separately; here, too many arrows on a diagram should be avoided: "An increase in number of arcs implies an increase in error probability [90]". Too many arrows inevitably results in crossing arrows that again reduces the legibility of the diagram: "Increasing the number of edge crosses in a graph decreases the understandability of the graph [91]". With the placement of arrows on a diagram, arrows of different meanings can be emphasized: "direct the Message Flow at a 90◦ angle to the Sequence Flow [88]".

It is recommended to place the elements on a diagram symmetrically which facilitates the reading of the diagram [92]. As regards placement, it is advisable to minimize the number of overlapping (connection) elements: "Nodes should not overlap edges or other nodes [93]".

General guidelines

Issues related to the labelling of the elements of the diagram have been brought out separately, the most simple general rule in the context of activities is that the label must be short ("Shorter activity labels improve model understanding [79]") and specific ("Use verb-object activity labels [81]"). It is recommended to use a business term catalogue, which defines and relates the main terms within a company [75].

As regards the presentation of the model, the topic treated in chapter 2.2.3 is stressed: "Associating pictorial elements with textual descriptions improves model understanding [94]".

As in summary the skill to read diagrams depends largely on experience, training of users must be emphasized in addition to modelling – modelling knowledge increases the ability to understand process models [78].

None of the notations "prohibit" such "violation" of the rules, but in practice, following such recommendations makes the model easier to read and, in conclusion, easier to use. A functionality which checks some of the rules referred to above (such as the layout symmetry) and brings out the parts of the diagram which have not been taken into account in compiling the diagram has been added to the modelling softwares.

Most of the recommendations given here have been proposed in the context of process diagrams. In our studies, we observe complete process models instead of single diagrams. At the same time, we can see (Chapter 5) how the recommendations given in the context of the diagram are reflected also in the use of the process model as a whole.

2.2.3 Diagrammatic versus textual process modelling?

In Chapter 2.1, we could see different possibilities for using a process model (in most cases, in the form of formal diagrams). In this chapter, we have looked at the form of facts to be reflected in a model if the process model is directed at a regular person (employee) in order to support the understanding of facts.

If a description is presented in the form of text, we do not presume that the user has special skills for reading the model – everyone can read texts. At the same time, it is difficult to communicate a large amount of facts or complicated facts through text, also, understanding (interpretation) of a text is ambiguous which poses a problem. A diagram is an instrument for correctly (unambiguously) transmitting different information concerning the organization, but at the same time, diagrams (especially detailed diagrams) are, in many cases, too complicated for people to use without a special training. We have observed in which context the diagram facilitates the understanding of a model and what makes it (especially as regards process diagrams) difficult for the regular user (employee).

One of the important advantages of a diagram is the, first and foremost, the presentation of the same "picture" to all readers [95] which is practically impossible to achieve in case of a longer and complicated text – people's attention and emotions differ in reading the facts, and, as a result, the picture composed differs by people. In addition, a given picture is easier to remember [95]; if the information is needed in the future, people preferably rely on a visual diagram. Looking at the description of an organization, both aspects are very important in this context: everyone must develop a common understanding of the important facts concerning the organization and these must be remembered.

The study by Larkin & Simoni [96] brings out when the diagram is worth ten thousand words – the diagram must aggregate the information dispersed in a text on one picture and represent it as a whole through an easily understandable scheme. This is a significant difference from the text as the reader cannot get all information at once from the text, the entirety forms in time, in the course of reading. This is also one of the most important points why the share of different diagrams has continually increased in time. To date, tables concentrating information, various diagrams of Excel, simple diagrams representing structure or context have become an integral part of daily documentation thanks to the above.

Previous characteristics have been brought out in the context of diagrams that are simple and intelligible without the description of the exact content of the elements of the diagram. If in the compilation of the diagram a previously defined notation is used, where different types of elements of the diagram carry a certain meaning (semantics) and clear rules must be followed in creating the diagram (syntax), the diagram becomes more difficult to read because typically such diagrams transmit details which may not be visible at first sight. In such case, simple "looking" at the diagram is not enough – the facts recorded during the compilation of the diagram must be read from the diagram.

In case of such diagrams, it is important for the reader to know the notation and to have experience in reading such facts. These aspects were analysed by Ottensooser et al. [11] in their study. They compared the intelligibility of the process model described as diagram and text by the students. Students who participated in the study were divided into two groups – one group had undergone BPMN training, the other had not. The study demonstrated that the description in the form of a text was understood well by both groups, at the same time, understanding the model in the form of a diagram was significantly easier for students who had received special training. Thus, the use of diagrams requires a training concerning the relevant notation, otherwise the facts reflected on the diagram are not correctly read. Taking into account the amount and complexity of facts as regards describing an organization, a diagram helps to present these facts in the form of a diagram more easily, in a more comprehensive way and unambiguously (in comparison with, for example, text), but at the same time, the notation in the back of the diagram adds the skill of reading the diagram that cannot be expected from a regular user by default.

Looking at the possibilities of the BPMN notation [36] upon describing a process model, we can find more than 200 different elements for bringing out different facts and details on a diagram – if all these possibilities were used in practice, the users would need a thorough training in order to interpret all these elements in detail and in a correct way. Looking at real models created in organizations for different purposes, the number of different BPMN elements used in process models is quite small, "fortunately" – a study by Zur Muehlen and Recker [9] highlighted that approximately nine key elements of BPMN are used in process models.

In addition to the simple selection of elements used on diagrams, the compiler of the model can follow rules which make diagrams easier to grasp for the reader and easier to use. Such simple rules have emerged from practice and been confirmed also in different studies that we covered in Chapter 2.2.2.

In summary, it could be stated that in compiling a process model, diagrams should be kept simple and easy to read, because, above all, it facilitates the work of process model users. If one desires to use process diagrams in the regular user (employee) context, a prior training is necessary where the meaning of the key elements of diagrams used in the model are explained and participants are taught to read (use) these diagrams. This is enough for the use of process diagrams to support the regular user in understanding complex systems.

The focus of the thesis is on the content of this chapter – how to make the use of process models wider and more active in an organization. The importance of the share of text and diagrams and their balance in the context of sustained use is treated in the study which is described in more detail in Chapter 5.

2.3 Process model use and reuse

In this chapter, we have examined how the process model changes in time [97] through different BPM lifecycle stages, who are the different users around the model and what needs to be kept in mind for the work with process models.

2.3.1 Process model use

BPM lifecycle begins with its trigger – an organization has a need to deal with processes. Similarly to the view of methodologies presented in Chapter 2.1.3 we can divide the trigger into three (Figure 4) according to the type of view [5] that is to be presented to the organization with the model – management view the purpose of which is the improvement of integral management and coordination of the organization; specialist view with the purpose of improving the processes (effectiveness); technical view the purpose of which is the application of technology in the organization (automatization).

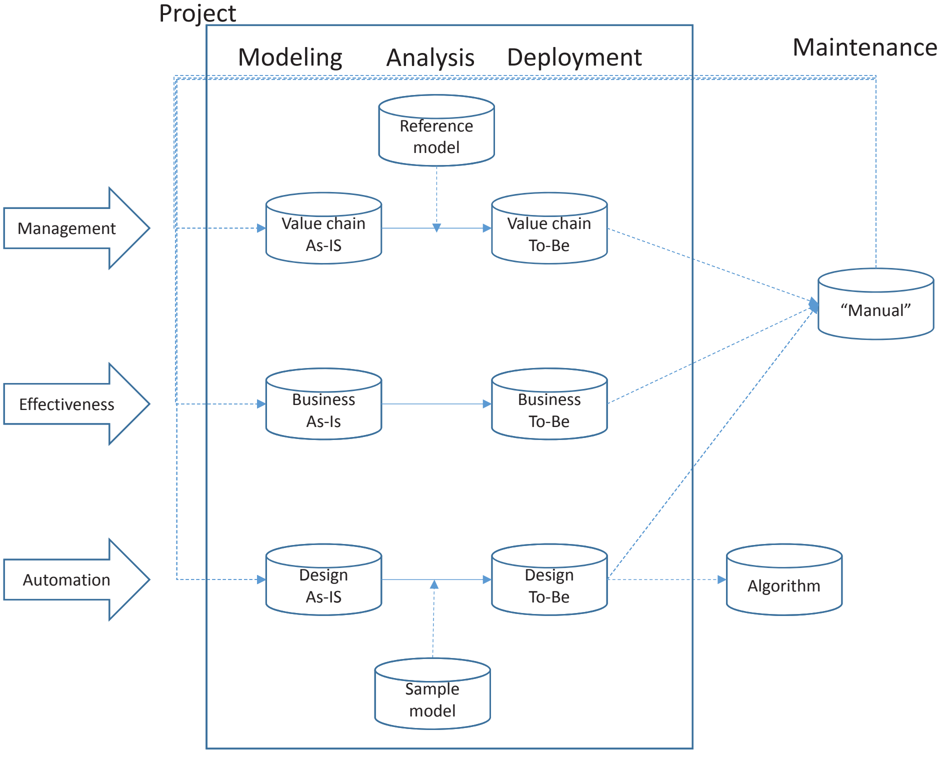

Figure 4: Process model change

In launching the project, specific purpose must be phrased and, on the basis of this, it must be decided how to describe processes, which methods are to be applied, which tools are to be used [14]. In launching the project, it is important to determine which information forms the base on which the process model is compiled – does internal documentation exist in the domain to be modelled, can existing process models be used that were compiled in the course of previous projects, how much should the employees and specialists be involved for specifying or modifying the previous information. Reference models of the domain [65] can be used as project input, which brings the experience of other organizations to the project. For instance, in the context of telecom, e-TOM [41] models can be used – they provide an integral structure in the compilation of the value chain on a general level and a process hierarchy in the compilation of more detailed models in case of business or technical view. Also, for many technical projects, the sample models [98] may be used, which brings out process logic on a detailed level that has a tailor-made technology or solution. As regards the input, the quality of the information to be used and its suitability for the project to be launched must be assessed.

The aim of the modelling stage is the creation of an As-Is model that suits the objectives of the process modelling project and reflects the organization's facts with the desired preciseness, detail and parameters. Volume, quality and format of input information determine the volume and content of modelling works – is it the specification of information, adding supplementary information or creating a model from scratch. If models previously created in the organization are used, attention must be paid to the semantic quality of the model used as input – whether the facts reflected in the model are up to date. If the level of detail of the existing model is more general than the model necessary in the context of the project (management view model is used in specialist view or technical view), information of the existing model must be made more detailed (decomposed) and the missing details must be added. If the more detailed model is to be used in a more general view (for instance, technical model in specialist view, or specialist view in management view), diagrams of more general hierarchy levels of the model may be used here by adding the missing information. In practice, the form and structure of the information used as input may pose a challenge – for example, using complex and technical diagrams which have been decomposed following the management of data quantities may not be suitable as a basis for the management view where the value chain [62] of the organization is typically used.

As a result of process analysis, new To-Be model is formed – following the application of different methods (Chapter 2.1.2), we will modify the As-Is model in the desired direction (Chapter 2.1.1). Comparison of two models provides us with assessments how the planned changes will change the organization and do they bring us closer (at least theoretically) to the objectives that we set in the beginning of the project. To-Be model provides a basis for making changes in the organization – it is a "tool" for the introducers of one part, "instruction manual" for process workers, of the other.

After the end of the project, the usage activity of the process model does not have to decrease – for example, as regards the introduction of work flow engine the process remains as the core of software and the basis of which the process is managed automatically. In the employee's view, the process model is primarily a description so that the person could get important information on the process; thus, the created model could remain in use as the "instruction manual" for process workers. An important thing to be taken into account in the continuous use of the model is its update – modification of facts according to the changes occurring in the organization. As regards small models, volume of work is small; however, for large organizations and detailed models, update is labour-intensive – constant modelling (update) continues after the project.

Initial use

A process model is created for a specific purpose and used in the context of a specific project – this first use is called Initial use [30]. The model is created, taking into account especially this initial use – who and for which purpose will use the model. Thus, in the course of software design, a detailed model of this domain of the organization where the introduction of software takes place is created. The model reflects actions, amounts of information and the actors in detail. Also, use of software is demonstrated in the model – by which activities the software is applied. The users of the model here are primarily IT-specialists who first design software on the basis of the model, create suitable solutions and perform the introduction in the organization. In the general analysis of the organization, model users are the managers of the organization who need a picture of the whole (not of a narrow field), granularity of information is much bigger here in comparison with an IT-project. Also, the model may reflect fewer components – for example, data view or actor view is excluded; division of labour is not reflected in processes, etc.

Re-use

If the model is to be used in another project outside the initial project in the context of which the initial use took place, then we will call such use Reuse [31]. In case of reuse, differences of projects must be assessed beforehand (aims, quality of information, modelled components) and consequently decided whether the model can (and should) be reused in the project to be launched.

First, it is important that the existing model covers the domain to be treated in the other project – in case a part is missing in the first model, the missing domain must be added in the model.

Second, it is important that the necessary elements and links would be reflected in the model and that suitable language would be used (syntax quality). Thus, in launching a process analysis project, description of operating guidelines (job descriptions) in the form of text is probably insufficient, if Root Cause Analysis or simulation methods are to be applied, as for these methods a clear series of activities – process diagram – is necessary. At the same time, if we wish to use the model as documentation, diagrams that are too technical (compiled in the context of an IT-project, for example) may be too complex for the regular user.

Third, the semantic quality of the model is important – does the model created in the past reflect the organization today. First, it must be taken into account that the organization changes in time and the facts reflected in the model may not match the reality as time has passed. Quality requirements set for the process model may differ by different projects as well.

Fourth, the level of detail of the information is important. In general models, for instance, we examine activity groups, the course of the process by departments, movement of documents, etc. In a more detailed model, we observe detailed activities and treat data on the level of information amount fields. Moving in the direction of more details when facts are described, we need to add information in the model; moving from a detailed model towards a more general description, we must generalize the amounts of information.

Sustained use

If the continuous use of the created model in the organization goes on after the project (initial use), then it is called the sustained use. A typical example here is an organization's knowledge base, used by the employees on a daily basis. Information structured on the basis of diagrams comprises documentation in comparison with documents in the form of text (Chapter 2.2.3), also, process model management software significantly facilitates the update of the facts of the model, and it is easier to ensure the semantic and syntax quality of the knowledge base as a whole.

Similarly to the re-use described above, there is needed assessment about the expenses related with the process model adaption for the context of sustained use. If process model is created for the technical users (modeller, analytic, software designer), then there is a high probability that model is not suitable for sustained use for the regular users, and there is needed additional changes taking into account needs of a regular user. In addition to the investment related with the process model adaption for the sustained use, process model update expenses have to be considered – daily use of process model needs continues update corresponding to the changes in the organization. Hence, before starting sustained use of process model, there is needed to calculate related expenses and estimate in parallel receivables which come from the usage of the model. Factor assessment method described in Chapter 4 was used by some organizations to clarify the appropriateness of the sustained use of the process model in their context and calculated involved investments and expenses needed to build up a proper context in the organization.

Our studies were focused mainly on sustained use – which factors and model parameters foster the sustained use of process models in the organization. Organizations attended our studies were already using process models in a sustained manner or were planning to deploy the sustained use of process model in the organization.

2.3.2 Knowledge re-use

First, we use the word "knowledge" refer to a state of knowing (know about), by which we also mean to be acquainted or familiar with, to be aware of, to recognize or apprehend facts, methods, principles, techniques and so on [99].

Peter Senge [100] highlights another important moment that we presuppose with regard to knowledge: "the capacity for action," an understanding or grasp of facts, methods, principles and techniques sufficient to apply them in the course of making things happen – know how.

Speaking of knowledge in the context of an organization, we refer to knowledge that has been collected and recorded in writing (to codified, captured and accumulated facts, methods, principles, techniques and so on) with the aim of communicating it to different people and to use it for the management of the organization as a whole.

From the angle of recording the knowledge in writing, we can divide knowledge into three parts [99]:

- **Explicit knowledge** – knowledge has been articulated and written down. We can bring a product description or a scientific formula as an example.
- **Implicit knowledge** – knowledge can be articulated and can be written down, if necessary. We can bring the process description covered in previous chapters as an example – it can be written down, if one has knowledge of the organization and modelling.
- **Tactic knowledge** – knowledge that cannot be articulated. For instance, it cannot be described exactly how a person recognises the other person's face [101]. At the same time, Tactic knowledge can be presented through explanations and descriptions, supporting the understanding of the knowledge and helping to communicate this knowledge.

Viewing knowledge from systems-theoretic perspectives [102], organizations are '**open systems**' that probably cannot be fully '**observed**' and therefore cannot be '**identified**.' As a result, these endeavors cannot be '**controlled'** in any strict sense or even to our specifications [103]. Thus, if we speak of modelling knowledge in the organization, we refer to the incomplete description thereof that can be used in management and in the communication of knowledge in the organization, which results in the improvement of control over the organization in the management of the whole.

Knowledge Management is the process of creating, sharing, using and managing the knowledge and information of an organization, important aspects of this are covered in detail by Grant [104] in his article. In different domains, there have been attempts to define as precisely as possible what is the knowledge that needs to be managed in a specific domain [105]. Donald Hislop has stressed three important points [106], which have made knowledge management topical especially during the last decades: the share of intellectual work has significantly increased in enterprises; increased competition obliges the competitive advantage to be highlighted and recorded; knowledge is the key asset for organizations to manage.

The central amount of information in knowledge management is Knowledge Base [13], where explicit knowledge that is important in the context of the organization is recorded as well as implicit knowledge concerning the organization and, where necessary, information that would support the understanding of tactic knowledge (tacit knowledge cannot be articulated but it can be communicated or transferred).

The term Knowledge Management System has changed in time according to technical possibilities of gathering, recording, analysing and sharing information more efficiently. Borgoff and Pareschi [107] give an overview in their book of which components, links, functionalities the modern knowledge management systems offer and to whom. Years ago, knowledge base was formed primarily by different work instructions and paper documents describing the organization; today, softwares offer functionalities for the analysis of gathered information, for the use of information and, in summary, also for the management of this huge amount of information in addition to the recording of information in different formats (texts, tables, diagrams, databases).

In the organizations that participated in our study, process models formed a part of the knowledge base which provided all information with process-centred structure. In many cases, multiple softwares were in use, and these were integrated into one whole – for example Enterprise Architect [108] for process models management, LiveLink [109] for document management and Wiki [110] for gathering and systematising the facts that emerge in the course of daily work (not thoroughly systematised).

2.3.3 Factors of process model use

Above, we examined primarily technical topics related to process models and different methods, next, we will observe which moments still need to be emphasized upon launching projects with the aim of creating models and using them in the organization.

For the projects to succeed, the existence of very different prerequisites and interaction of components is necessary so that the specific stage could succeed and the result would bring substantive benefit to the enterprise: training of the employees, project management, administration support. It is difficult to bring out an integral "set" of necessary prerequisites from a specific successful project; also, it would be difficult to introduce it in another organization as the context of carrying out projects in different organizations is different. In order to highlight important moments which must be emphasized in the implementation of the project for it to succeed, success factors are used [15] – factors where things must go right. For example, for a process modelling project to succeed, the following success factors have been brought out [30]: Management Support, Modelling Expertise, Project Management. Specific metrics is difficult to define and measure for such success factors, rather, these are important topics emphasized from the practice of experienced organizations, on the one hand, and implemented in organizations wishing to introduce process-related activities in their context, on the other hand – a check-list of topics that need to be considered.

Similarly to success factors, many authors have dealt with the negation of a success factor – failure factor [111] – topics through which one can follow or predict the failure of a project. Through the success factors, important context for the success of a project is brought out; failure factor, however, is more like an indicator which needs to be kept an eye on to be able to know of a possible failure in advance. Thus, the failure factor is more like a "tool" for the project manager for recognising negative trends which have led to the failure of a project on the basis of other enterprises' experiences.

Different articles on success factors are usually focused on a specific part of a BPM life cycle, i.e. on a sub-project – such as process modelling [30] or later reuse of a process model [31]. This is primarily due to the fact that in different stages the factors are different and the importance of the same factors varies by different stages. For instance, "Clear goals and purposes" has been brought out as success factor both in the context of process modelling project as well as a part of the later use of the process model as a part of the knowledge base in the organization. In the context of the project, the focus here is strictly on the result of the project first and foremost; these results may be very different (changing the organization's structure, introduction of technology, process analysis), unlike the knowledge base context where describing the organization and introducing its use is the purpose. From a different angle, software has also been highlighted as an important factor – in the context of the project, from the viewpoint of the software modeller, in the context of later use, primarily the ease of use of the software for the regular user.

The factors are typically focused on the important objects of a processes-related activities. From one side, there is the modeller of processes and a process model in the process modelling (or analysis) project, where success factors are: Modeller Expertise, User Participation, Communication, Modelling Method, Modelling Language, Complexity, Project management. From the other side, the process model and the user of the process model primarily concentrating on the introduction of the process model or the use thereof in a later stage of the BPM life cycle where are highlighted following important success factors: Task Motivation, Goal Orientation, Modelling Expertise, Knowledge Networking, Software usefulness, Source credibility, Perceived Semantic Quality, Perceived Usefulness of the Model, Perceived Ease of Interpretation. Both sides tie in with a methodology and software used in the creation of the process model and also in the later use. In addition, the wider context wherein all the above will be carried out is very important – the specific organization and related aspects. Each of the important objects mentioned above (Modeller, Model, User, Tool, Organization) from different stages of a BPM life cycle and related success factors is (either directly or indirectly) also connected to the late use of the process model in the organization (sustained use).

For assessing the influence of factors, different authors have highlighted variables that can be measured in a more exact manner than the success factors and, if necessary, measured and followed in time. Thus, here the quality of a process model [112] or the real use of a process model in a later stage of a BPM life cycle can be measured and assessed [31]. Tracking the meters along with the success factors gives the institution a feeling of practical influence of different factors in a specific institution – knowing the influence and significance of different factors on different variables, the institution can more consciously influence the factors, and through this, to direct the results of different projects.

Our study [28] was not aimed at analysing the factors of a narrow project but rather at highlighting the factors in a BPM life cycle as a whole with the purpose to assess them in the context of different institutions, and analysing which factors influence the wider use of a process model in an organization – sustained use.

3. PROCESS DOCUMENTATION ASSESSMENT

3.1 Introduction

In contemporary business process management practice, it is common for business process models and associated documentation to be produced in the context of specific projects, be it software development projects, business improvement projects, quality management projects or audits [113]. Often these models are used in the project where they are produced, but not consulted nor systematically maintained past the project, thus creating so-called “pollution” in the organization’s process model repositories.

Several success factor models are available to measure, explain and predict success of process modelling initiatives [30], [15]. These models shed light into the factors that determine whether or not process models are perceived to be useful by the relevant stakeholders (among other dimensions of process modelling success). Other studies have focused on assessing the quality of process models [114] or improving the syntactic or semantic quality of process model repositories by means of refactoring [115]. However, these studies focus on diagrammatic process models, whereas in practice processes are documented in various ways, ranging from free-text documents, such as manuals of policies and procedures, to structured documents (e.g. legislative documents) and tables [116]. Additionally, process models are captured at different levels of granularity and from different perspectives depending on the intended usage.

In this setting, this chapter studies the question of how to assess the current state of business process documentation in an organization, with a specific emphasis on organizations where the process documentation is available in different forms (ranging from highly unstructured to highly structured) and at different levels of completeness and granularity. The chapter starts by discussing previous work on business process documentation. On the basis of insights gained from this review of previous work, we outline a possible approach to organize the process documentation in an organization in the above setting. Finally we present a validation of this process documentation assessment framework via case studies.

3.2 Theoretical Background

Descriptions of activities are necessary for various purposes and for various users: a list of general activities is presented in a workplace-centered manner in a job description in order to define the role and responsibilities of an employee; the job description includes a detailed sequence of (important) activities with different possible scenarios; the general process map of an organization includes important areas on a general level and indications of links between those areas.

Each such document (process model) has its purpose and users, based on which one must find the level of granularity that suits the description in the document, the expressed quantity of information and links, and a format for presenting information in the model. Such documents are prepared with various tools at different times and by numerous people. This brings us to the question: how would it be possible to manage these quantities of information as a whole so it would satisfy the various needs of an organization, be in a suitable format for a user, and reflect the organization sufficiently correctly and be up-to-date [117]?

By looking at larger organizations, managing such quantities of information is a highly complicated and time-consuming task – how can managing such quantities of information be arranged? How can duplicating information (and double updates that accompany this) in various models be avoided? How can existing documentation be re-used efficiently when creating new models and outputs? What kind of software applications should be used for presenting information to various user groups?

In the classification of documentation [118] describing an organization, parameters “business area” and “granularity” have been reflected. These bring out how the existent process documentation covers the organization [119] [120]. This view is important for understanding which part is described with a different process model and at which level of detail, how the descriptions are interlinked and, in many cases, overlapping.

In addition to linking the models to the areas of the organization on a general level, it is important to bring out a parameter on a general level, which demonstrates the purpose of the use of the model so far, and accordingly its usability for other purposes more widely.

An important parameter which has been emphasized to a great extent also in the articles is the quality of the model [72]: primarily the content (semantics) and the quality of the language used for describing (syntax). These parameters are important but in highlighting the general context and classification thereof the determination of the parameters in question is relatively time-consuming. Also, the quality of the model can always be improved, and in general planning and choosing the direction, it is not an insurmountable problem in most cases (but can be time-consuming).

Also, it is not important to emphasize technical parameters during planning on a general level, such as a modelling tool or different resulting outputs. Taking into account modern software solutions, different outputs can be generated from the tools and information can be transformed between different platforms, where necessary. The amount of time spent can be relatively large but, where necessary, it is feasible without the involvement of the majority of process workers.

We included a parameter which reflects indirectly and on a more general level the aspects described above in our model – the format in which information and structure are presented in the model: simply as text, structural text, in a table, figure, systematised figures (model). This parameter highlights the central structure in modelling the information, demonstrates the methods that could be used in analysing the amount of information and provides indirect reference to quality through the above. In this regard, the pragmatic quality is also important – the general format of the model shows who the given amount of information with this structure could be targeted at.

As regards these three parameters (area, granularity, structure), it is important to note that these are easily defined and easily understandable for the wider circle of users – we can classify the existent documentation relatively quickly and the result is enough for obtaining a general picture on the basis of which the situation today can be assessed and further activities planned. In conclusion, we are using documentation for classifying easily definable parameters that provide a structural and visual picture of the documentation. The offered systematising views are easy to understand as a whole, and easy to use by different parties involved in the development and use of documentation.

Parameter – structure

When looking at documentation that describes an organization, various diagrams and tables are used with increasing frequency to point to important elements or emphasize important connections in a description in a visual manner – the structure of an organization, response matrix, communication schema with other organizations. The following is a look at various possibilities for presenting information in documentation and an analysis of the positives and negatives of various formats depending on the user of the information.

The text is the most natural and easiest format for writing down activities in order to communicate important information in an organization. The advantages of text primarily include its wide use and the presumption that all people can read and understand texts. At the same time, a problem that lengthy descriptions face is the complexity of structure and connections – when the number of facts and connections that are being presented is large, then various readers are very likely to understand the description differently [121] [122].

In order to point out important topics and connections between those topics in a complex text (description) to a reader, we can add a clear structure to the text – we will divide the text into subdivisions and refer to those in order to emphasize connections. The most typical of examples is any legal text [123] where paragraphs are marked (with numbers in addition to a title), and in order to point to important links, reference is made to a specific marker (number) for added emphasis to the connection. When structure is thus delineated, it facilitates understanding the document as a whole and is also helpful when making references – a reader will understand which subdivision of the whole is cited.

This presentation of structure (division of complex information) is a principal element of structural analysis [4], the central component of which is hierarchical decomposition – a complex object is divided into smaller (simpler) parts to help a reader understand and grasp it more easily. Such structural division (top-down) enables to present a large and complicated system through its smaller parts; the small parts are easier to understand and an integral structure helps keep the whole picture intact, making it easier to comprehend the larger picture (bottom-up) [124].

If a hierarchy can be used to delineate a structure by following one aspect (dimension) of information, then a table is a tool for depicting two-dimensional information: a reader finds information easily based on two dimensions by following either the rows or columns of a table [125]. In addition, a table provides an overview of the existence or absence of information (connection) when the quantity of information is large. Such tables are good for presenting a matrix of responsibilities, for example, for work positions (rows) and areas (columns), where the cells of the table include text that details responsibility and its content.

Often, such tables are created by "hand", using simple tools ("Word", "Excel"). However, such tables can be generated automatically as output of process modelling software (for example, usage of documents according to the role in the process). Process modelling and analysis software uses the central data repository [46] as initial data for such output, from which necessary information is obtained by a query and displayed in a suitable format to a user.

The previously described tools help add the desired structure to a text, making finding information from a text and comprehending the whole picture easier. If necessary, structure can be explained by a separate diagram for establishing a visual depiction of important objects or connections. As an example: Data Flow Diagram – to express data transformation in a system [126]; Use Case Diagram – to identify actors and system functionality on general level [40]; Entity Relationship Diagram – to describe database structure [127]. When describing an activity model with a Processes Diagram, the important activities of the process being described are pointed out, as is their sequence [14]. Depending on the notation, various important links and facts can be established in addition to activities and the sequence: emphasizing actors by adding swim lanes; determining data context of an activity; highlighting decision points in an activity chain. Wider use of diagrams could be limited by the proficiency of readers in understanding facts and links presented in a diagram – knowledge of diagram notations and an experience of grasping information presented in such a format.

3.3 The Process Documentation Cube

In order to map process models used in an organization and analyse the management of process models as a whole, we propose a structure (Process Documentation Cube) that reflects three essential aspects of documentation – business area; the level of granularity; format (structure) of the model.

A process documentation assessment model is intended to help analysts to holistically map the process documentation of an organization and to assess this documentation with respect to three aspects:

- **Completeness:** the documentation covers all processes and gives a balanced overview of all processes at different levels of granularity via a process hierarchy.

- **Consistency:** different documentation items are consistent with respect to one another. This includes consistency among different types of documents (e.g. textual documents and diagrammatic process models) and across process documentation at different levels of abstraction.
- **Comprehensibility and updatability:** it is possible for all relevant stakeholders to comprehend and to update the process documentation.

The proposed process documentation assessment model takes the form of a cube (cf. Figure 5) consisting of three orthogonal dimensions. The first dimension relates to the type of process being documented (*area*), while the other two refer to the level of detail (*granularity*) and the level of structuredness (*structure*) of the document itself. Each document or group of documents is mapped as a cell in the PDC based on its classification along these dimensions.

The first dimension, namely *area,* is based on Rummler's framework [128], which divides processes into three classes: operational, support and management processes. Operating processes produce outputs directly relevant to external customers. Support processes (e.g. financial and human resource processes) are those required in order to maintain the infrastructure (incl. human and material resources) required to perform the operational processes, while management and those intended to oversee and control other processes and to maximize value to other stakeholders (e.g. shareholders).

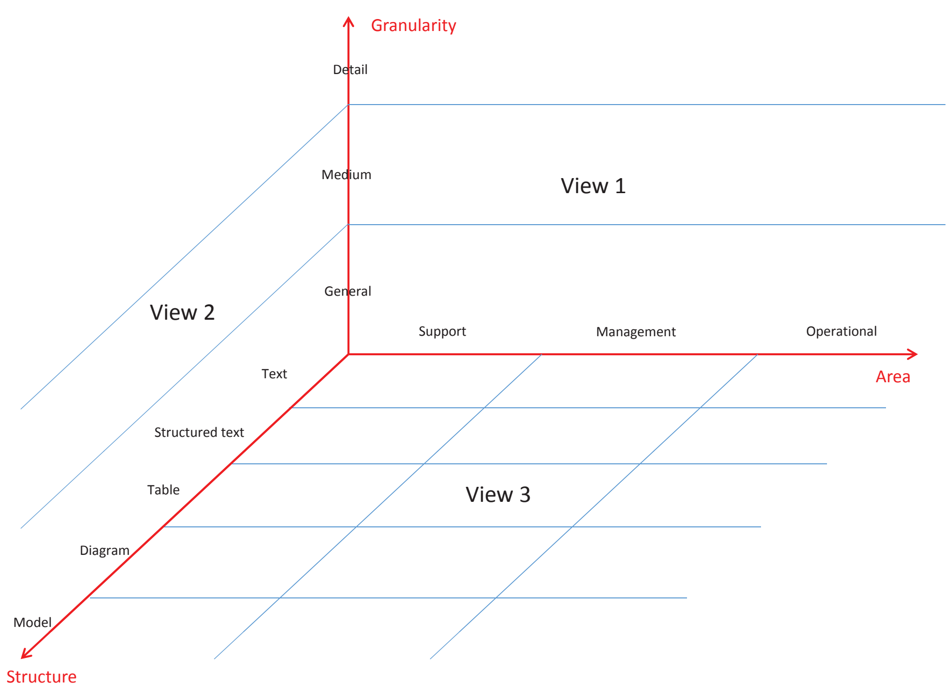

Figure 5: Documentation cube

The second dimension (*granularity*) represents the level of detail (or level of abstraction) of the documentation: general documents, medium-level documents, and detailed documents (cf. process hierarchies [68]). Different granularity levels are suitable for different purposes. For example, for a new employee who has to understand the value chain and their role in the organization – it seems reasonable to have a top down approach. A customer who is interested in getting more information about services should follow the process at the middle or detailed level.

There are many possible ways to define the granularity of process documentation. In order to reduce the scope for subjective interpretation, we rely on the classification provided by the SCOR framework [129], which identifies the following levels:

- **General or Top-level:** Process documentation focused on defining the scope of the process (what is done in the process);
- **Medium or Configuration-level:** focused on showing how processes are executed with the aim of communicating this information to a wide audience;
- **Detailed or Process element-level:** Process documentation that provides details of the process on an element-per-element level (e.g. individual tasks).

The third dimension (*structure*) relates to the level of structural meta-data of the document. Here we distinguish between text (plain text without any prescribed structure), structured text (a text with a strict structure), table (a table with a defined structure), diagram (a simple drawing or diagram that does not follow a prescriptive modelling notation or is not stored in a repository, e.g. a Visio or PowerPoint drawing) and model (a diagram abiding to a prescriptive modelling notation and maintained in a repository). Different types of structure are suitable for different stakeholders. For example, legislative documents (structured text), which are widespread in the public sector, are easy to read for lawyers but hardly accessible for stakeholder without a legal background. These latter stakeholders may prefer simple diagrams or tables.

In addition to capturing the location of each document along the above dimensions, the PDC includes *consistency links*. A consistency link exists between two documents D1 and D2, if there is a mechanism in place to ensure that an update to D1 leads to an update in D2 and vice-versa. This mechanism can be automated (a document generated from another) or manual. Naturally, consistency links allow us to assess documentation consistency across different dimensions of the cube.

Since a three-dimensional cube is difficult to visualize and comprehend at once, it is convenient to view the PDC through its two-dimensional views. Each view allows one to assess different aspects, as explained below.

3.3.1 View 1 – Area-Granularity

The first view comprises the area and granularity dimensions. This view gives us the whole picture of the documentation and allows us to assess documentation completeness. Specifically, it allows us to assess if there are documents about different areas (horizontal layout) and covering each level of granularity (vertical layout).

If there is any empty area on the diagram, then it may raise a question – whether we missed a document during documentation gathering or there is a gap in the documentation? For example, in the public sector the main processes are usually described, but not enough attention is paid to the supporting processes and management activities – a gap in the detail documentation.

3.3.2 View 2 – Structure-Granularity

The combination of structure and granularity form the second view. This view is useful for assessing comprehensibility and updatability. Indeed, different stakeholders need different types of documents and at different levels of granularity. Thus ensuring comprehensibility of process documentation by all stakeholders requires that documents are available in different structures and levels of granularity. Plain text is probably most common format for daily documentation – there are no any restrictions or assumptions – all employees can read text documents. In the public sector several legislative and regulatory documents are used to describe the organization activities, rules, etc. All these documents are described as a structured text. But these voluminous and specialized texts are not easy for employees or clients to comprehend – the latter preferring plain text, simple diagrams or combinations thereof. Models targeted at a wider user community could include supportive diagrams and tables that highlight, for example, the structure of the system as a whole (structure of the organization as a figure, structure presenting the links between data in the form of a table) or structure supporting the local description (context diagram, process diagram). Business analysts and managers on the other hand may take full benefit from process models or formal tables for process analysis and tracking.

Thus, in the planning of process documentation for various target groups, models targeted at the wider user community could be "brought" in the given view, taking into account the horizontal axis, to the middle – texts could be more structural, technical models and diagrams simplified to the regular user.

The level of detail brings out roughly who the documentation is targeted at – general figures are rather for clarifying the whole and grasping it on the level of management, more detailed figures are rather targeted at the specialist for understanding the details. Very detailed diagrams are primarily directed at system analysts and IT specialists for analysis and automatization of data management.

3.3.3 View 3 – Area-Structure

The third view covers area and the structure. This view allows us to assess completeness, comprehensibility and updatability. It gives an opportunity to decide which processes (areas) are documented as structured text (e.g. legislative documents), which ones are presented as a table, which documents are generated from a model, etc.

If an organization uses a sophisticated modelling tool, this view is a convenient structure to fit the model outputs onto the documentation map. If most of the facts about the organization (roles and structure, activities and processes, data, etc.) are in the model repository, and different documents are generated (job description, process description, data usage, etc.), documentation update is simplified.

View 3 highlights the parallel layers of documents and gaps that may exist in these layers. For example, legislative documents have to be in place, but additional documents covering the same processes, possibly generated from a business process model also need to be in place for employees performing day-to-day tasks.

In case of main processes that involve also the customer in many areas (especially service), we need documentation targeted at very different user groups – the lawyer, development department, employee, customer. At the same time, as regards support functions carried out in the organization's backoffice, information on carrying out the work is, in many cases, necessary only for the employees of one department.

In summary, different areas need descriptions directed at different user groups; it could be analysed and designed on the View 3.

3.3.4 Recommendations for the PDC assessor

We summarize different recommendations which could be followed during the creation of the PDC and assessment of documentation (knowledge base) in the organization. Most ideas have already been described in Section 3.3, or popped up in the course of our case studies (Section 3.4).

1. Process documentation has to cover uniformly trapeze (Figure 6) on View 1.
2. Documents overlapping each other on View 1 should be merged.
3. Documents on General and Medium level on View 2 must be linked.
4. There could be links between documents on Medium and Detail level on View 2. The number of links is relatively big, and for this reason proper software tool has to be used.

Our study described in Chapter 5 highlighted the area on View 2 and View 3 (in the middle) where documentation is more actively used by employees on a daily basis:

5. Documents located in the left (pure text) should be "shifted" to the right on View 2 – pure text documents should be structured.
6. Documents located in the right (model) should be "shifted" to the left on View 2 – there has to be a sufficient amount of textual description behind every process diagram in the document (output generated from the process model repository).
7. Documents located at the top (pure text) should be "shifted" down on View 3 – pure text documents should be structured.
8. Documents located in the bottom (model) should be "shifted" up on View 3 – there has to be a sufficient amount of textual description behind every process diagram in the document (output generated from the process model repository).

3.4 Case studies

3.4.1 Methodology

From a methodological perspective, we followed a multi-case-study approach described in Chapter 1.2. First, an analysis of the problem in light of existing literature was conducted, leading to an initial definition of the PDC.

The structure of PDC and the instruction about the implementation was prepared. Next, the perceived usability of the PDC was tested by means of six case studies using a three-phased data gathering and hypothesis validation method. In each organization, data collection was performed via three meetings:

1) The first meeting consisted of an interview with a process analysts or the organization's stakeholder who would be closest to playing this role. The aim of the interview was to make an inventory of all process-related documents in the organization, without restriction on the type of document. For each document we sought to obtain information about three aspects: document creation; maintenance/update; and usage. There were 4 main questions about each phase: who; when; what and how. Copies of the documents were also collected.

2) Based on collected information, the first author prepared three views of the PDC for the organization in question, and highlighted potential gaps and ideas for document integration. The PDC, gaps and integration ideas were discussed during a second meeting with the same stakeholder as in the first interview, plus additional analysts and subject matter experts invited by the first stakeholder. The aim of the second meeting was to gather feedback on the accuracy of the PDC and the pertinence of the gaps and integration ideas.

3) Feedback from the second interview was summarized in a final report that was sent to the participants of the second meeting. Based on this report the last meeting was organized for a wider audience, including management. The aim of the third meeting was to gather feedback on the perceived usefulness of the PDC – how much clarity such structuring and visualisation of documentation brought about in the organization, and to what extent did it facilitate strategic discussion in the context of process documentation discussion.

Finally, feedback gathered during these case studies was used to refine the definition of the PDC and to identify directions for extension and improvement.

3.4.2 Implemented case studies

As a preliminary evaluation, the PDC was applied in six public sector organizations in Estonia. The choice of public sector organizations is motivated by the fact that these organizations are more inclined to disclose their internal documentation – and in many cases this documentation is publicly accessible. This allowed us to freely collect details that would be more difficult to access in some private companies.

After these six initial case studies, PDC was additionally tested in four organizations (two of them were private companies).

We focus on three representative organizations corresponding to the following situations:

- Agricultural Registers and Information Board – processes are not documented in a structured way, but instead unstructured documentation is in active usage;
- Labour Inspectorate – processes are described in a structured way and these structured models are in active usage;
- Estonian Tax and Customs Board – processes are described in a structured way but the structured models are not in active usage; instead other unstructured process documentation is in active usage.

3.4.3 Case study 1 – Agricultural Registers and Information Board (ARIB)

This is a typical example of an organization where mainly text is used for a process description. View 1 gives an overview of the documentation (Figure 6). The trapeze emphasizes the document hierarchy; lines are used to represent consistency links between different documents.

Processes are described through the document "Procedure description". There are ~400 different procedures and the main complaints about these documents were that update is too complicated; documents are not updated properly; quality and usability degrade over time. The update problem is directly related with the size of the document – all descriptions are too voluminous. Instead of a simple diagram with a brief description, there is a bulky text with cross-references inside. These cross-references make the update procedure very complicated and time consuming. Finally, it is very difficult for the reader to grasp general structure of the process and understand all nuances correctly: loops in the process, exceptions, parallel tasks, etc. This case illustrates that if an organization is interested in starting a process modelling project, the PDC provides a structure to design the project outputs and fit these outputs (documents) into the daily documentation and to move toward more structured documents (e.g. Figure 7 → Figure 8). Figure 8 highlights how to bind the process model with the documentation: lines indicate documents that are generated from the model; green boxes highlight new documents or old documents in the new format.

In this organization, a process modelling tool would simplify documentation update by generating different outputs (e.g. documents) from models. During the assessment, attention was focused on an upcoming process modelling project – what tools should be used; how to involve and train employees; how to use the process model, etc.

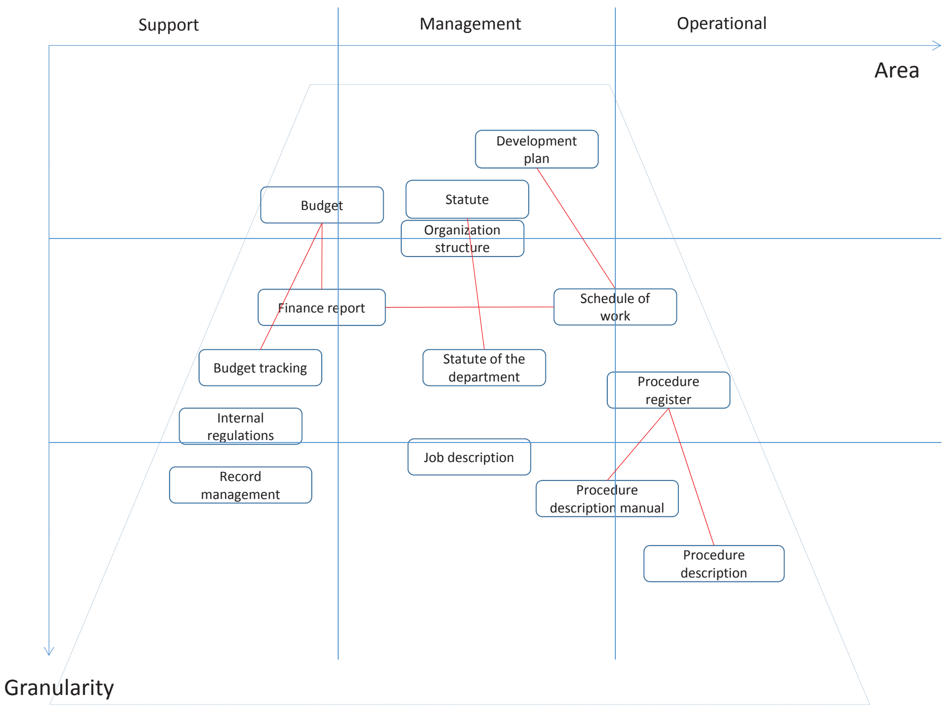

Figure 6: View 1, ARIB

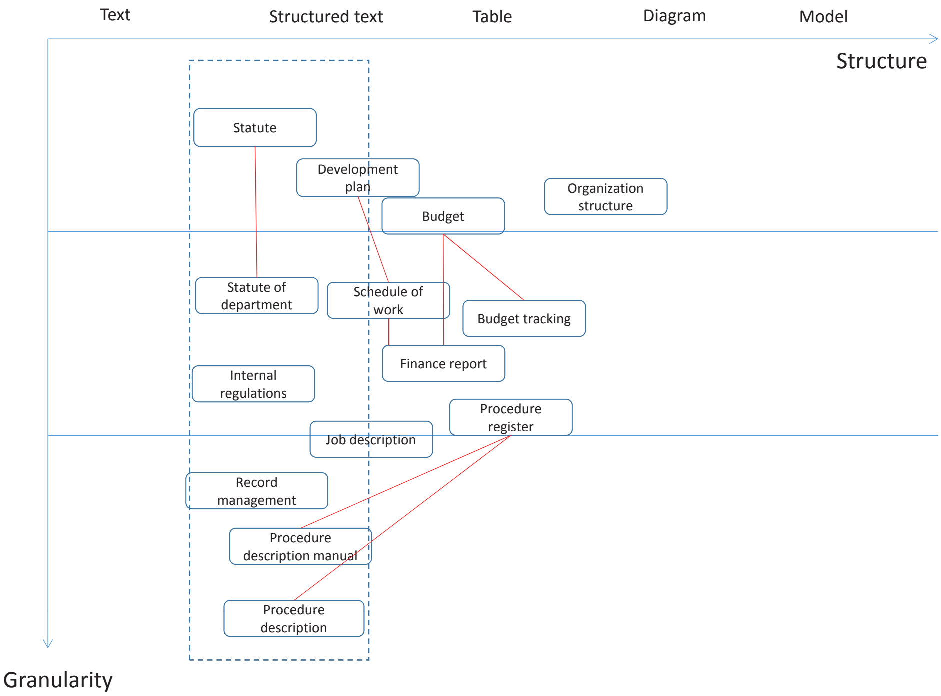

Figure 7: View 2, ARIB

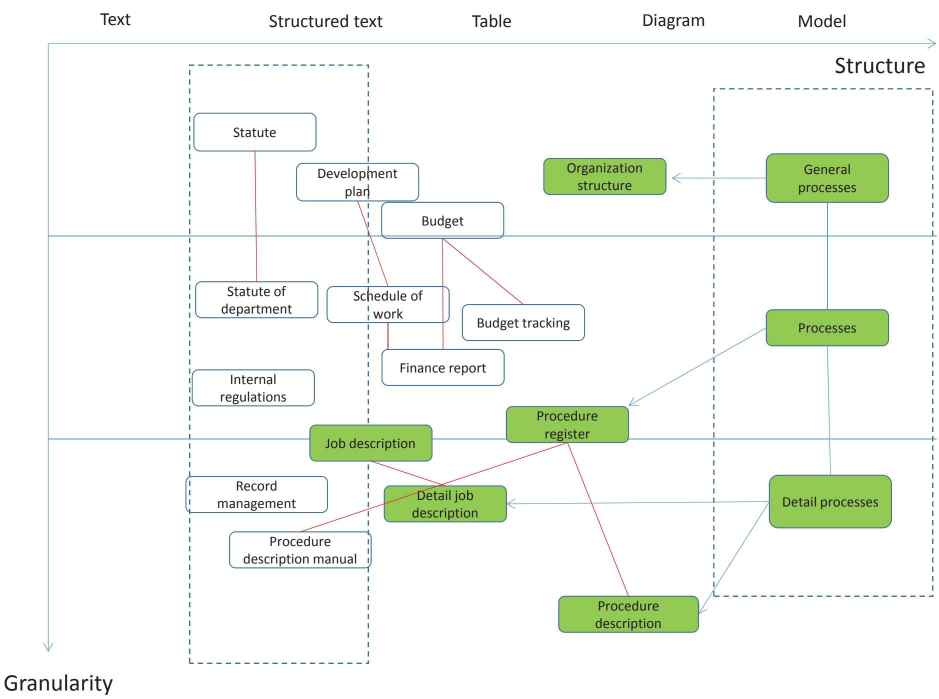

Figure 8: Proposed “to-be” View 2 for ARIB

3.4.4 Case study 2 – Labour Inspectorate

This case study led to a very different picture, as shown in Figure 9 In this organization, there is a sophisticated process modelling tool in use, and number of documents have been generated from the models managed by this tool. In this case, the main gap we discovered was that the process hierarchy was not properly modeled and accordingly, documents on the general level were missing. The green boxes in Figure 9 show where this missing process hierarchy would go in the PDC and how this hierarchy could be bound with other documentation.

An update procedure of detailed documents (job description, daily procedures, data usage etc.) was in place. The process hierarchy gave better understanding about the full processes and a big picture about the whole organization. Upper layers of the process hierarchy give a structured base for general documents like goals and strategy. Additionally, process hierarchy could be used as a table of contents for the process model – flexible entrance into the detail level of the process diagrams.

View 3 gives an interesting result here (Figure 10): there are two layers of duplicated documents: the upper circle is highlighting legislative documents (that have to be used in theory) and more structured documents (that employees use in practice).

During the assessment process, the main attention was focused on the comprehensibility and usability of the process model outputs. The document cube gave a structure to design changes.

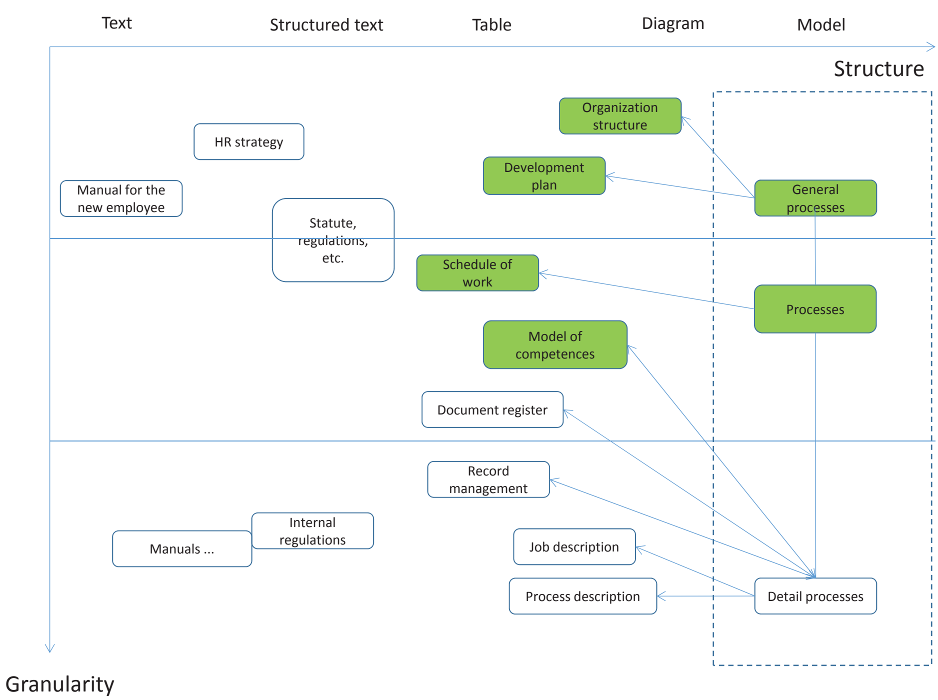

Figure 9: Proposed "to-be" View 2 for Labour Inspectorate

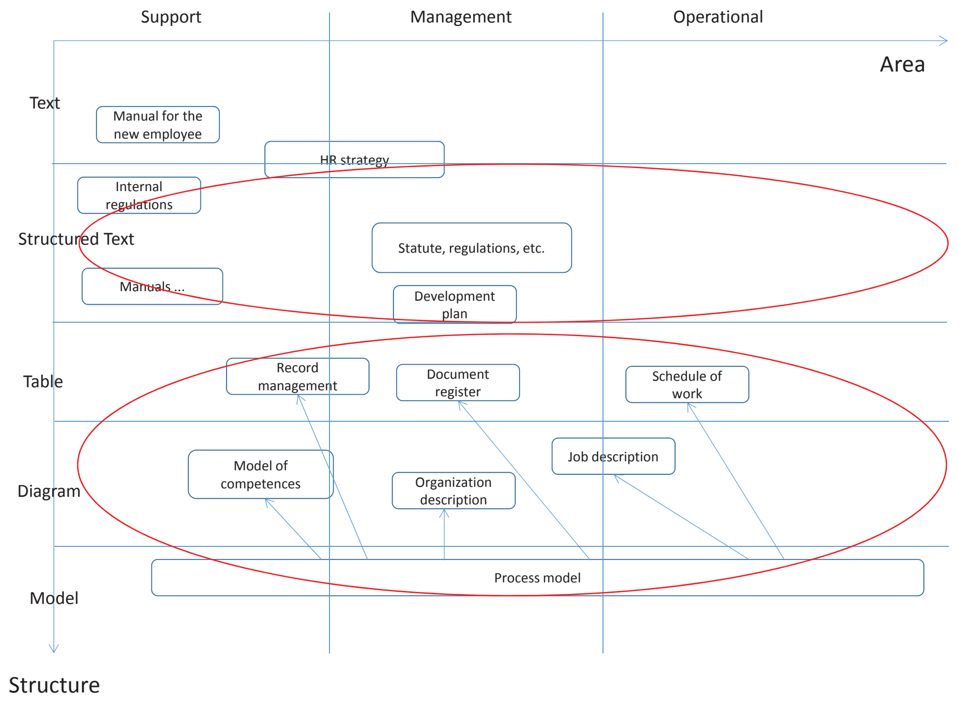

Figure 10: View 3, Labour Inspectorate

3.4.5 Case study 3 – Estonian Tax and Customs Board

Case study 3 highlights the problem of lack of integration of process models produced by a modelling project and daily documentation in the organization. The goal of the implemented process modelling project was process optimization and process change. The project produced high-quality process models. The analysis phase of the project highlighted different problems and a To-Be model was produced. If we look at the project from the business process analyses perspective, then result is excellent. Unfortunately, there were not any output to the daily documentation, and for this reason, the model was not used by the employees (Figure 11).

The main problem in the long term here is the process update. After the project, there is not enough time and attention to the process model. The model is not used and updated in daily life. The "death" of the model is just a matter of time.

The PDC was an excellent tool to design changes in the documentation and find suitable outputs from the business process model to support deployment of the model (Figure 12). These changes brought together employees around the process model and made them think about the daily processes, problems, needed changes, etc.

There main issues were identified. First, there was a lack of a proper process hierarchy – table of contents. Second, more documents were needed for daily work of employees. Finally, process modelling tool simplifies documentation update, and even more important, intensive use gives motivation for the model update.

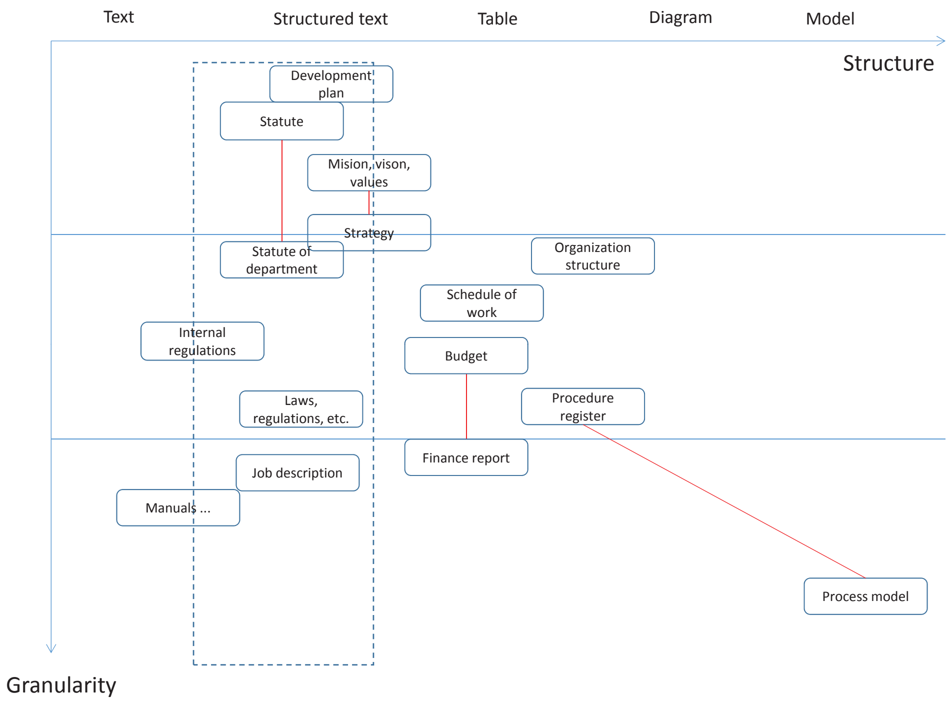

Figure 11: View 2, Tax and Customs Board

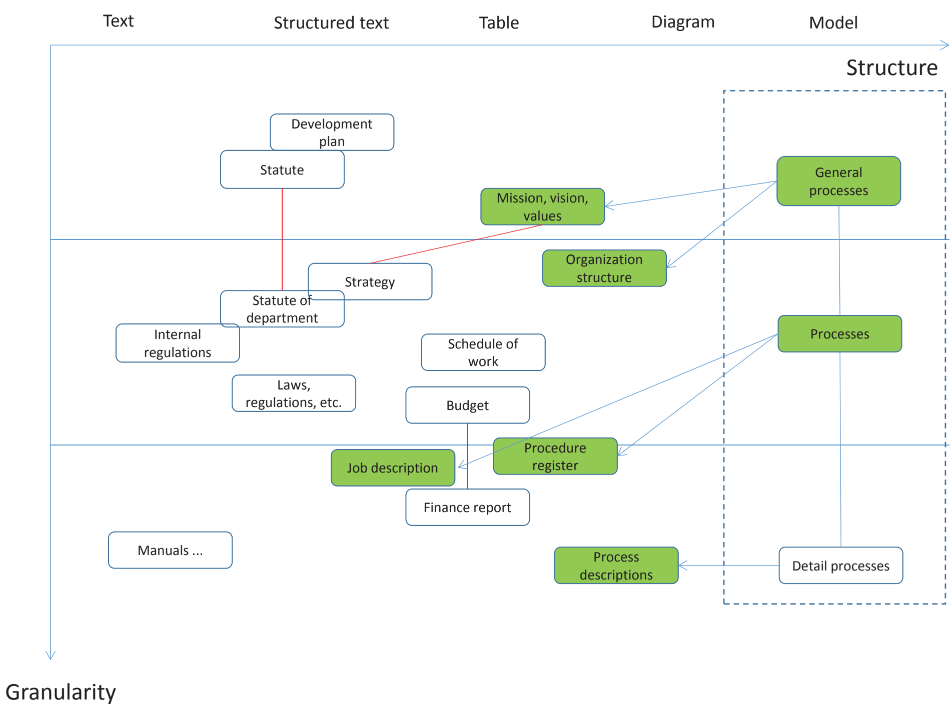

Figure 12: Proposed "to-be" View 2 for Tax and Customs Board

3.4.6 Conclusion of case studies

One can distinguish three *patterns of process documentation* from the case studies:

Pattern 1: If entire documentation is in a textual format, then information is re-used to some extent when creating various models; at the same time, it is labor-consuming to depict models in a textual format when the system changes. As a result, the quality of information deteriorates – descriptions fail to correspond to reality after a while, and due to that, their use declines (ends) [130]. The organization used the document cube in process modelling planning phase – design process model outputs and integrate these outputs with daily documentation. In the given case, the whole organization will get an idea of how the process model to be created is integrated in the existent documentation targeted at different user groups, and how the update procedure of different documents will be carried out.

Pattern 2: The second pattern is a typical example of how various quantities of information develop in an independent and parallel manner "thanks to" new process modelling and analysis tools. This indicates that the use of BPM tools has not yet been deployed in an organization where analysts use new tools for specific projects, but apart from that, the larger part of an organization uses textual documents – the output of the process modelling project is not oriented to employees. This is typical for organizations that have not thought of the wider use of the result in the organization before the process modelling project, and therefore, overlapping and non-integrated models have begun to emerge. The PDC allowed us to identify outputs that could be generated from the process modelling tools and thus to integrate the process models with daily documentation.

Pattern 3: The third pattern depicts a more mature organization where the output of process modelling tools has been integrated into daily usage and information is regularly updated. The mapping and analysis of the whole picture pointed to various possibilities for a more efficient use of BPM tools, as well as better integration and management of daily (process) documentation in an organization. In the given case, PDC is of help in carrying out the "inventory of process models" that results in the planning of a better integrated use of process documentation and easier update.

When someone is a creator or a user of a model in an organization, they often fail to see the full picture of documentation – where information gets duplicated, how to manage administration of the whole, how to integrate outputs of modern tools into a system of managing information. Such simple graphic depiction and analysis of information helps examine how the process models are managed and find possibilities for documentation improvements in an organization.

3.5 Three years later

We conducted a PDC update in organizations that participated in the study, and as an example, provide Estonian Agricultural Registers and Information Board's (ARIB) diagrams which depict the changes that took place over the last three years.

Today’s As-Is diagram of ARIB (Figure 14) shows that clear progress has been made in the direction that was planned together 3 years ago (Figure 13). The current pattern is similar to Pattern 3 (Chapter 3.4.6) that was explained earlier – process model is integrated with daily documentation. Some important changes, when comparing Figure 13 (To-Be model from three years ago) and Figure 14 (As-Is model today):

- Detailed descriptions of processes and managing those now takes place in the business process modelling software environment.
- The list of the processes (before, it was managed with an Excel table) is in a structural format (process map) and can be used in an interactive manner in the business process modelling tool.
- Job descriptions now include diagrams.
- New diagrams have been added to the management level (Strategic Map) which describe the organization as a whole from various points of view and indicate the context of various subjects in that entity in a visual manner.
- Strategy documents and diagrams are linked to the general process map.
- Some of the procedural descriptions are still in the old (textual) format; updating those is considerably more complicated, compared to new tools and the process-centric approach.

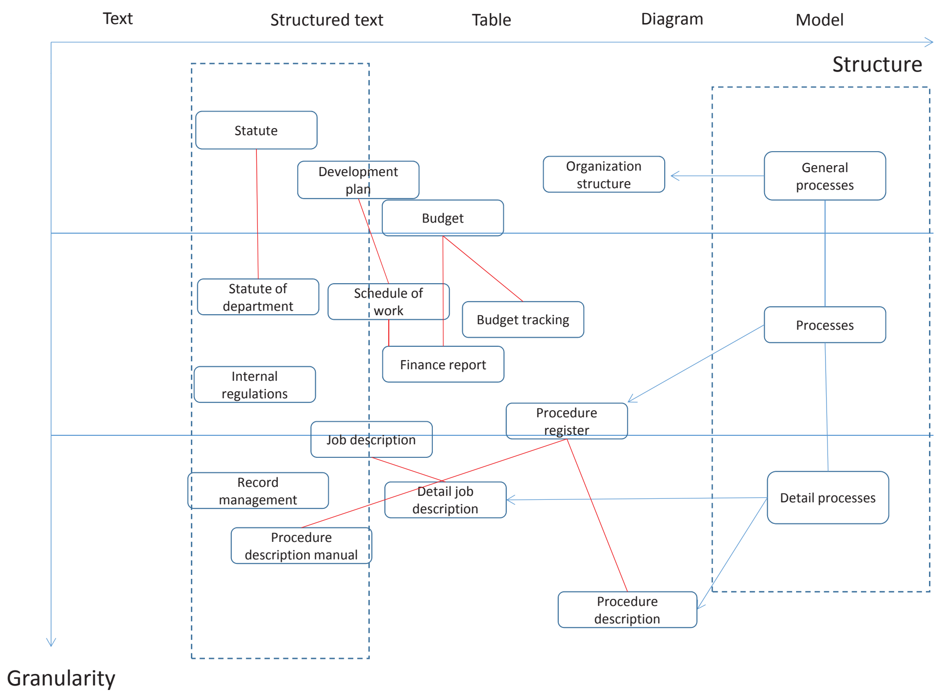

Figure 13: Proposed "to-be" View 2 for ARIB (2014)

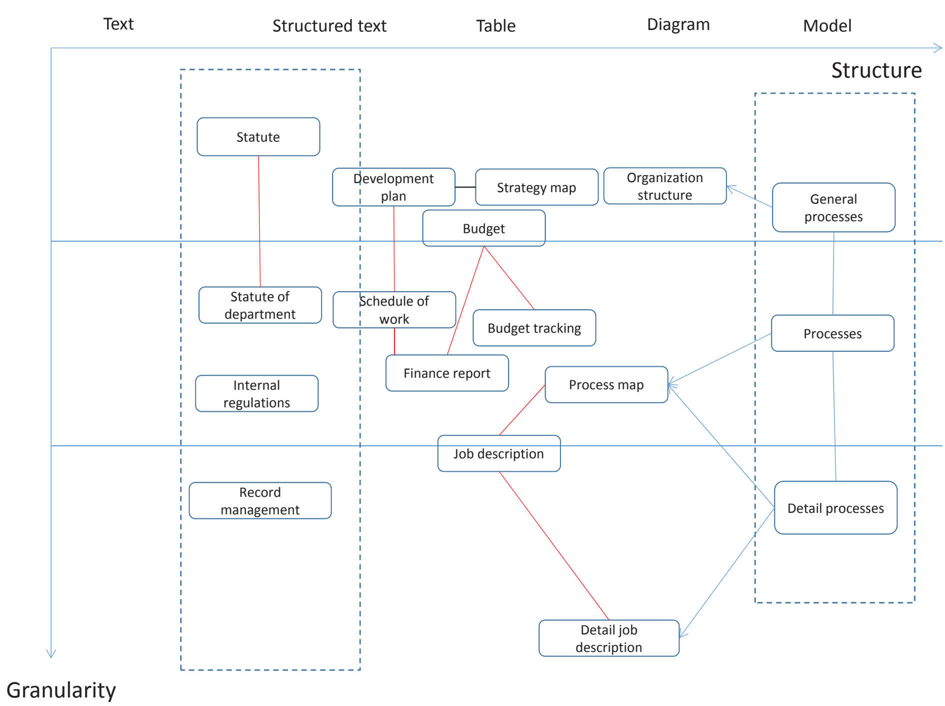

Figure 14: View 2, ARIB (2016)

In conclusion, it can be said that a large part of the plan has been implemented by now; at the moment, only deployment needs to be completed – covering the entire organization with new documentation. The current As-Is view of PDC (Figure 14) was used by the organization to deploy new systems and plan their integration in the organization – document management system and the data warehouse application.

3.6 Conclusion

The PDC gives a simple structure for mapping the organization documentation and to assess its completeness, consistency, comprehensibility and updatability. In organization with comprehensive process documentation, the PDC allows one to identify gaps and integration opportunities. Meanwhile, if an organization is starting a new process modelling project, the PDC can be used for planning purposes in order to determine how the process models will fit with other documentation.

We are not aware of previous work that addresses the question of how to visually map organization-wide process documentation with different structure in order to identify gaps and integration opportunities. A recent work [116] proposes a tool for integrated diagrammatic and textual process description, but it does not address the above question. Some related work has addressed the question of what is the perceived value of process modelling and process models [131] or what are the main obstacles and pitfalls of process modelling [113]. Other work has discussed the importance of wider usage of process models – beyond analysts [132]. This latter work argues that participation and involvement of employees in the process modelling project is important and correlates with quality and usability [30] [15]. However, this body of work is orthogonal to the PDC's objective of identifying gaps and integration opportunities.

4. FACTORS OF SUSTAINED PROCESS MODEL USE

4.1 Introduction

Business process management (BPM) is a central component of information and operations management practices in many modern organizations. A common practice within BPM projects or programs is to capture the business processes of an organization in the form of business process models. Process models serve manifold purposes, including preserving and communicating process knowledge as well as analysing, redesigning and automating processes for the purpose of continuous business improvement [133].

Process models are generally created in the context of a specific goal [134]. For example, a model of an order-to-cash process might be created in the context of the deployment of a new enterprise resource management system in an organization. However, said model can be subsequently re-used for other purposes such as training of new staff members or continuous process improvement. If process models are to serve as a unifying vehicle for managing business processes, it is desirable that process models are re-used over a sustained period of time, past the specific initiative or project where they were created.

Various studies have elucidated and analysed the determinants of knowledge sharing and reuse in organizations [122] [135]. In comparison, the reuse of process models – as an integral component of an organization's knowledge base – has received less attention. As reviewed below, some studies have considered the question of process model use and reuse, but only in the context of specific projects, rather than sustained use over time.

In this setting, we focused on the question of what factors determine whether process models are used in a sustained manner or only for the purposes they were initially created?

To address this question, we followed a multi-case-study approach described in Chapter 1.2. In the first phase, we analyse the literature on success, impact and reuse factors of process models and more broadly knowledge reuse. Drawing upon multiple previous studies, we build an a priori factor model of a sustained process model use. In the second phase, we conduct case studies in four organizations. In these case studies, we assess the current state of each organization with respect to the identified factors on the one hand, and their level of sustained process model use on the other hand. Based on data collected during the case studies, we establish possible relations between the identified factors and the observed process model use in the organizations under scrutiny. After these four case studies, the assessment instrument is additionally tested and elaborated in seven organizations.

4.2 Theoretical Background

Process models are generally created and initially used in the context of specific BPM initiatives or projects with certain purposes in mind. Process models could be created, for example, in the context of a process improvement project [136] or within the scope of a software integration project [137], and used for the purposes of the project where they are created.

Once created, a process model or collection thereof can be reused for different purposes outside the scope and timeframe of the project. For example, a process model created in the context of a software integration project could be used later in the context of a process analysis and improvement project or vice versa. Such repeated use is called ‘reuse’ – a repeated use of the process model for different purposes or tasks than initially envisaged [31]. Process model reuse can occur in a one-off manner, or can recur over time.

Sustained use – called ‘continued use’ by some authors [138] – occurs when a process model or collection thereof is reused on a regular basis over and over again past the project in which they were initially created and for different purposes or tasks. This regularity makes that the model becomes part of the general knowledge of the organization, or of a subset thereof.

Thus, the question of what are the factors that determine sustained process model use is intertwined with two other questions, namely: (i) what determines the success of projects or initiatives where a collection of process models is created and initially used; and (ii) what determines the fact that a given process model or a collection of process models is re-used in a sustained manner past the project or the initiative where they were initially created.

In literature review, we focused on papers on knowledge and more specifically, process model reuse in organizations. Additionally, papers on process modelling as an essential presumption of process model reuse were linked into our review.

4.2.1 Process Modelling Project Assessment

Process modelling project success factors have been studied by Bandara et al. [30] who propose a model of critical success factors of individual process modelling projects. The focus is on project success and the initial use of the process model during the project. This model is composed of eight success factors and five success measures. The success factors include project-specific factors and modelling-related factors. Examples of success factors are ‘Modelling Expertise’ and ‘Modelling Tool’. The purpose of success measures, on the other hand, is to assess the initial use of process models and the impact that such initial use creates in an organization. Success measures in Bandara and Rosemann’s model include, for example, ‘Model Quality’ and ‘Process Impact’. The proposed model summarizes previous studies on process modelling success factors and is later on tested in practice.

At a more upstream level, Eikebrokk et al. [139] have proposed a theoretical model of determinants of business process modelling in organizations. In other words, they study the question of why certain organizations have practiced modelling over long periods of time, whereas others have not. In our study, however, we focus on a complementary question, namely: given an organization where process modelling has been practiced, what determines the fact that some process models get to be used on a sustained basis while others are only used in projects where the models are created.

Another related study is the process modelling impact framework of Bernhard and Recker [24]. This study synthesizes different studies on process model use and proposes a model to explain a perceived or actual impact of process modelling along an organization's objectives. This model highlights seven factors related to process modelling initiatives and process model use. However, the model in question is not intended to assess process model use per se, but rather the organizational impact that process model use creates.

4.2.2 Knowledge and Process Model Reuse

Determinants of knowledge reuse in organizations have been studied by Watson and Hewett [12], who proposed a success factors model (eight factors) influencing knowledge reuse and user contribution in an organization. Examples of success factors in their model are 'Training in Knowledge Reuse' and 'Value of Knowledge'.

Many researchers have tested different factors based on DeLone and McLean success model [112]. This model focuses on the information system and knowledge usage in an organization and influences between different factor groups. Success s related to different quality dimensions (information, system, service) have been studied by Jennex and Olfman [138]. Success factors tested in their model (nine factors) are, for example, 'Linkage (of the information)' and 'Management Support'. Jennex and Olfman [140] provide a comparative review and synthesis of determinants of knowledge management success, as well as a detailed comparative analysis of four success factor models in this area. Their synthesis puts forward a number of organizational, tool and user-related factors that we take as input for constructing of our a priori model.

Use of process models in particular as an important part of BPM has been covered by different authors [8]. Success factors related to process model reuse have been studied by Nolte et al. [31] who propose a set of factors that determine process model reuse after the process modelling project. Their model consists of 16 factors (arranged into five categories) including 'Software Ease of Use' and 'Modelling Expertise'.

An important component that has been indicated in aforementioned articles is the quality of information base, first and foremost in the context of a process model [31] or of knowledge base [12], but also more widely on various aspects of tools and organization [140]. The issue of quality has been separately addressed in article [114], where specific reference is made to quality parameters in the context of different important objects (such as the modeller, tool, aim of modelling); it is also analysed how different aspects of quality are interrelated and influence important objects in the field of BPM.

Quality of process models [141] is more narrowly treated in articles [142] [143] where the reuse of process models from the angle of the end user is analysed – which parameters of process diagrams facilitate better understanding of information by the reader of the process model and reduce the number of mistakes in the creation of models. Here, the parameters of model quality metrics are, for example, 'Complexity' and 'Size'. We did not involve a more detailed quality metrics (variables) associated with the process model. Rather, the focus was on more general factors that the organization can support and influence through different activities. Thus, these topics have been incorporated into our model through more general factors such as 'Ease of Interpretation' (clarity and ease of the model for the end user) and 'Structure' (presentation of complex and extensive information through easily understandable structure) [81].

Process model reuse may occur at different levels in granularity which is analysed by Holschke et al. [144]. We focus on process model reuse in the context of modelling rather than on the question of continued use of a given process model over time.

The next section introduces the a priori model of sustained process model use, that we will base on models of success factors focused on different phases of BPM.

4.3 Assessment Framework for Process Model Use

This section introduces the proposed assessment framework for process model use. First, we will provide an overview of the framework and its rationale. Next, we will introduce the success factors. Finally, we are going to introduce an assessment instrument for applying the framework to a specific organization. Definitions of different factors have been provided in the Appendix A.

4.3.1 Overall Structure

The proposed assessment framework is grounded on a life cycle model of a BPM programme [145]. In this model, a BPM programme consists of a number of BPM projects that evolve concurrently (or sequentially), each one following a four phase life cycle: (1) project preparation; (2) project implementation; (3) deployment and initial use of the produced models; (4) post-deployment and sustained use of the models.

The project preparation phase is concerned with the identification and scoping of business needs and goals, resource planning, risk analysis, and other project preparation activities [146]. This phase brings the category ‘Organization’ into our framework.

The project implementation phase includes activities where the modelling team investigates which processes are involved, collects relevant data about these processes, produces the process models, performs corresponding quality checks and discusses the models to relevant stakeholders [5].

The project deployment phase includes the publication of models to their intended audience and other activities related to the initial use of the model within the direct scope of the project. For example, individual models can be used for process analysis, re-design and implementation of an IT system to support the execution of the process [137]. Process model-related factors are classified under the category ‘Process Model’.

The post-deployment phase encompasses activities where the models are used for purposes beyond the scope of the project in which they were produced. This phase includes ongoing maintenance of a model (e.g. corrective or perfective updates from outside the scope of the project), reuse of parts of the model in other process models, and perusal of the model [147]. We define sustained process model use as regular, post-deployment use by multiple stakeholders for different purposes. The post-deployment phase brings into our model the category ‘User’ – which draws together factors pertaining to the (long-term) users of the model.

4.3.2 Categorization of Factors

First, under each category, we collected factors from different success factor models to delineate essential aspects in the category. Further, we examined the topics emphasized in articles on the phases of BPM lifecycle in the context of different categories. In order to avoid overlapping between factors under a category, we have followed the orthogonality rule between factors under every category. Analysis has been summarized in Table 2. Next, we will present a summary explanation by categories of factors, following the BPM lifecycle.

To start with, a process model has to be created. Process modelling projects are usually complex and voluminous, thus different authors have highlighted different critical aspects/factors to be emphasized (‘Stakeholders Participation’, ‘Management Support’, Information Resources’, ‘Project Management’, ‘Modelling Expertise’). Furthermore, technical choices regarding methodology and tools that influence wider use of the model also after the end of the process modelling project, are important as well (‘Modelling Methodology’, Modelling Language’, Modelling Tool’).

While creating a process model, it is important to establish an information base that forms the basis for necessary analyses and planning. There are two criteria for the user who will be using the model in a sustained manner after the project: usefulness and ease of use.

Table 2: Success factors under different categories

	Organi-zation			Modelling							Model					Tool		User		
	Management Support	Clear Goals and Purposes	Subjective Norms	Modelling Expertise	Stakeholders Participation	Information Resources	Project Management	Modelling Methodology	Modelling Language	Modelling Tool	Richness	Knowledge Quality	Value of Knowledge	Structure	Ease of Interpretation	Ease of Use	Usefulness	Competence	Motivation	Knowledge Networking
Process Modelling																				
Bandara et al. 2005 [30]	x			x	x	x	x	x	x	x										
Raduescu et al. 2006 [148]	x	x	x	x	x	x	x	x	x	x										
Rittgen 2010 [149]			x		x	x														
Lu and Sadiq 2007 [150]								x	x	x										
Process Model use																				
Nolte et al. 2013 [31]			x									x	x		x	x	x	x	x	x
Rosemannn 2006 [151] [113]		x	x	x	x		x	x	x	x	x	x	x	x	x	x	x	x		x
Recker 2006 [152]																x	x			
Mendling et al. 2010 [81]														x	x					
Knowledge Management																				
Jennex and Olfman 2005 [140]	x	x	x	x											x	x			x	x
Jennex and Olfman 2006 [138]	x										x	x				x				
Watson and Hewett 2006 [12]													x	x		x		x		
Yew Wong 2005 [153]	x	x	x													x	x	x	x	x

Usefulness is related, first of all, to the existence of necessary data ('Richness'). Second, data has to reflect real processes ('Knowledge Quality'): (1) during the process modelling project, different facts and relations in the model must reflect real processes; (2) changes in the process have to be reflected in the model after the project (the model has to be updated). Finally, all this information should be valuable to the user ('Value of Knowledge') – the user will get the information he was looking for.

The basis for ease of use is, above all, clear and comprehensive structure of the process model. Process models are complicated and thus, a flexible structure (process hierarchy) is extremely important to decompose facts first and find out needed information later ('Structure'). In addition to the general structure, smaller groups and views of information (diagrams, lists of facts) must be well presented to the reader ('Ease of Interpretation').

Proper software tools have to be used to gather information from the process model. First, we summarize technical issues (accessibility, system quality, service quality) into the factor 'Ease of Use' – there should not be any technical obstacles in using software. Functional aspects of the software have been collected under the factor 'Usefulness' – a functionality necessary for browsing process models is provided.

A model of good content and technical quality together with comfortable software create the necessary prerequisites for the user of the process model user – an experienced and motivated employee, interested in gathering information from the process model and ready to contribute feedback for model update. First, competence concerning the process model and tool use is needed ('Competence') – many authors emphasize training and learning under this factor. The user has to be motivated to use knowledge for different purposes (getting new information, verifying important facts and relations) in daily operation ('Motivation'). Finally, (positive) experience about sharing information in the organization is necessary ('Knowledge Networking') – first in finding the necessary information, then using it and finally sharing it with colleagues.

Everything described above will be carried out in a specific organization with technical and cultural environment that has developed over the years. Success factors that characterize general attitudes in the organization toward BPM initiatives are under category 'Organization'. The first question in the context of organizations and projects is – why BPM? The answer should be clear and communicated in the organization ('Clear Goals and Purposes'). In parallel, attitudes of different employees toward BPM initiatives and the process model have been reflected ('Subjective Norms'). Success factor 'Management Support' was already mentioned in the context of process modelling project. Management support is the key to success during all phases of a BPM life cycle. For this reason, we have moved the success factor 'Management Support' from the category 'Process Modelling' to the category 'Organization' in the context of our framework.

4.3.3 Assessment Instrument

Our assessment framework consists of a number of factors, which affect different types of process model usage in different phases of a BPM programme. The proposed factors were derived from different studies highlighted in Section 4.2 and analysed via the categorization given in Section 4.3.2.

Each factor is rated with reference to *activities* performed as part of the BPM project and considered by the organization's assessors as supportive of the factor in question.

The choice of activities associated to a given factor is left open for assessors. For example, in assessing the factor 'Modelling Expertise', possible activities may include 'in-house development of modeller expertise', 'training of employees in process modelling' or 'outsourcing of modelling expertise'. The factor 'Management Support' could be assessed through activities that reflect positive (or negative) attitudes of management towards a BPM project or programme – for example, 'management participation in the BPM project' and 'mentions and recognition of BPM projects at board meeting(s)'.

Factors could be described (assessed) either through planning or already accomplished activities. If a project has already been implemented, then the real activities that constitute a factor (for example, modelling activities which reflect the 'Modelling Expertise') should be highlighted.

With reference to activities, each factor is rated via five-point scale with following labels:

- –2 – no activity has been undertaken or is planned regarding a factor;
- –1 – activities are planned, but not yet realized regarding a factor;
- 0 – there are activities partially (or fully) realized regarding a factor, but without real influence;
- 1 – activities have been fully realized regarding a factor with some positive results;
- 2 – activities have been completed regarding a factor and have led to observable results.

Based on the rates of factors, an average for every category (first row in Table 2) was calculated.

In order to assess whether process models are used continually every day, we checked technical user logs. Process model was considered as used in a sustained manner when:

- process model use had continued after the process modelling project (1 year or more);
- users group expanded after the project;
- users were using the process model on a regular basis (at least once per day by at least one process worker in their performance of the process).

Our focus was on the process models where active use was carried on over the long period in the organization: first initial use during the process modelling project followed by active use over a period of more than one year after the initial production of the model.

4.4 Case Studies

We can recall from Section 4.1 that the overarching question of the study is the following: what are the factors that determine whether process models are used in a sustained manner, or only for the purposes they are initially created? Having proposed a framework for assessing process modelling factors, we have decomposed the research question into following sub-questions:

- which factors of the a priori model are highlighted by organizations as most relevant for sustained use?
- are the grades assigned by process modelling stakeholders in an organization to the different factors in the a priori model in accordance with the actual use of process models after the process modelling project has been finished?

Below, we will discuss the organizational setting of case studies, case study protocol (including data collection steps) and the findings.

4.4.1 Methodology

To address these questions highlighted above, we followed a multi-case-study approach described in Chapter 1.2. We determined that the case study method was suitable in our context as it allowed us to collect qualitative insights from practicing experts embedded in organizations where process models have been produced and used. The possibility of gathering such qualitative insights was considered to be important, given that the proposed a priori model – though derived from a synthesis of previous models – is new and not previously validated in practice. For this reason, an exploratory approach was selected to validate our a priori model and investigate raised questions in parallel [154].

First, an analysis of the problem in the light of existent literature was conducted, leading to an initial assessment model including the assessment instrument described in Chapter 4.3.

Four case studies were conducted to validate the model and the assessment instrument. Multiple organizations were involved in the study in order to increase reliability and generalizability of the findings. Data collection procedure was based on focused interviews designed to put into evidence concrete activities performed by the organization in support of each factor, as well as influences between factors and sustained model use (or lack thereof).

In parallel with the case studies, a small survey was carried out where we collected feedback on the importance of factors. The goal of the survey was to get additional feedback from the experts of the field and rank factors based on their knowledge in our assessment model. Process managers (21) of the companies, who participated in case studies, gave feedback on the influence of the factors on the sustained use of the process models via ranking the assessed factors of the objects by importance.

4.4.2 Case Study Setting

We selected four organizations as case studies from different points along two spectra: public-private; medium-large [155]. The four organizations are:

- Bank of Estonia – a large constitutional public institution that operates under its own statutes and under the law, with a long history and experience with BPM.
- Estonian Telecom – a large private company, recently formed via the merger of mobile, IT and broadband companies. Both units have had a long experience with BPM.
- Estonian Agricultural Registers and Information Board (ARIB) – a medium-size public organization implementing different projects that encompass business processes.
- Elisa Estonia – a medium-size branch of a private international telecom service provider with many years of experience with BPM.

The case studies were conducted during 2014–2015. Below, we will present the case study protocol and summarize the findings.

After these four case studies, the assessment instrument was additionally tested and elaborated in seven organizations.

4.4.3 Case Study Protocol

First, an initial contact was established with a member of the organization in order to present our broad vision of BPM success factor analysis.

Second, an assessment was organized in cooperation with the BPM team of each organization, including the BPM project and process owners. The assessment framework for process model success factors was introduced to the BPM team (~15 min) before the assessment. Next, we covered the success factors following the BPM life cycle, e.g. time line. The data collection was based on the structure of a priori model described in Section 4.3.2. For each success factor, we drew up a list of activities which had either been carried out or were planned to be carried out, and which characterise or support the given factor. The BPM team was asked to explain the results of these activities and the influence achieved in their organization. Information was recorded in a structured table composed of the following columns: factor; activities related to the factor; results of activities, grade for the factor; comments and ideas. An example of a part of a completed assessment table is presented in Table 3 Columns 'Activities', 'Results' and 'Comment' were filled in during the interview. The interview lasted for about two to three hours. Data collections were conducted in the context of recently implemented BPM projects and in terms of complete BPM programmes with the focus on process models used afterwards. The table filled in during the interview was the basis for the factor assessment after the meeting. We applied the assessment instrument described in Section 4.3.3. Grades were stored in the fourth column in the table – 'Grade'.

Third, separate meeting for the table and assessment results review were organized with BPM teams of each organization. During the meeting (about one hour) important improvements and details were collected and added into the table (columns 'Activities' and 'Comments'), if needed, the grades of assessment were justified (column 'Grade'). BPM team members ranked the assessed factors by importance in the context of categories, thus giving their evaluation to the importance of factors to influence the reuse of a process model. The first had to be a factor that, in assessor's opinion, has the most significant impact on the reuse of a process model (number 1), and the last had to be a factor with the lowest impact on the reuse of a process model in assessor's opinion.

Table 3: Example of an assessment table filled in during interviews

Factor	Activities	Results	Grade	Comment	Rank
Modelling Expertise	An outside consultant was used for process modelling. Our people (development department) attended modelling activities and obtained experience concerning process modelling. After the project in-house training was organized.	Excellent expertise in the context of the project. Modelling experience for our modellers.	1	BPM knowledge is sufficient for process model update today, but backup is needed.	1
Stakeholder Participation	Employees did not attend the project. Department managers attended the BPM training organized after the project.	BPM (basic) knowledge for our department managers.	0	More users should be involved in the BPM project in the future.	3
…					

The fourth meeting (about one or two hours) was aimed at reviewing the actual usage of process models in the organization. For each model referenced in previous meetings, the number of users and frequency of usage of the process model during the process modelling project and after the project was determined. Information was provided by the project manager of the BPM programme, the administrator(s) of the intranet and process modelling repository where models were maintained and published. Based on these data, we classified the process models into those that had undergone sustained use and those that were not used in a sustained manner according to the definition of sustained use previously introduced.

Three to seven people participated in the study from each organization, in conclusion 21 professionals.

4.4.4 Findings

Every organization had a diverse know-how of BPM projects and a different perspective of process model usage. Our findings during the interviews and analyses of the BPM programmes of these organizations highlighted factors that affected process model usage in a sustained manner after the experience of having completed several BPM projects.

There were diverse experiences concerning process modelling (projects) in every organization that participated in the case study (average of category 'Process Modelling' 0.9). Organizations highlighted mainly the influence of *project modelling activities on process model quality*: "The initial models were too technical and of poor quality, keeping in mind the wider audience." It was underlined in the interviews that quality depends directly on modeller's experience and skills.

Process model quality was the central topic in the context of models used in a sustained manner in organizations (average in the organization higher than 0.5). The structure of the model (factor 'Structure') was highlighted as a key in making technically complicated models suitable for regular users and reaching sustained use after the modelling project: "The only thing we elaborated after the project was the general structure of the model". Every other factor under the category 'Process Model' was already supported and had achieved the necessary level during the process modelling project.

The average grade along the "process modelling tool" was relatively high (above 1.0). In process modelling phase, software functionality was emphasized as an attribute that fully supports the modeller upon entry and analysis of information; from the perspective of process model users, simplicity both regarding the uses as well as the user interface was underlined first and foremost. Modern BPM tools provide versatile functionality for process modellers and *different types of reports and views extracted from the process model for consumption by a wide range of users*. In all organizations, software used in the project or its outputs were integrated into other systems of the enterprise "after the project, the model was integrated into our knowledge base".

In our assessment, we gave a high grade to factors under the category 'User' (average 0.4). *Practical experience was especially highlighted*, different trainings and courses were of secondary importance in our interviews: "Our users grow along with BPM projects". Factor 'Competence' was always higher than factor 'Motivation'. Sustained use was achieved with models where the grade of factor 'Motivation' was closer to the grade of factor 'Competence'.

Success factors related to organizations were variable (organizations averages between –0.4 and 1.1) – even low grades for factors in the category 'Organization' were not an obstacle for starting to use the process model in a sustained manner in the organization. Success factors (especially 'Top Management Support ') under category 'Organization' were more likely *related to process modelling project*: "Our management decided to start BPM activities in our organization five years ago". Sustained use of process models was rather a bottom-up initiative (especially in organizations where the grade for category 'Organization' was lower) related to BPM team or a small group of people: "Business people participating in the project started to use the model on a regular basis after the project was finished". Organizations where the grade for category 'Organization' was higher emphasized *positive influence on the users* (employees): "The active use of the model by the management set an example to the rest of the members of the organization".

4.4.5 Limitations and threats to validity

The findings of this research should be construed in the light of typical limitations and threats to validity of a case study research, particularly with regard to low generalizability. To mitigate this threat to validity, we conducted multiple case studies (multi-case-study approach) and supported the findings with observations across the case studies. We also selected case studies from different types of organizations in different domains (public vs. private large vs. small). However, all four case studies were conducted in the same geographical region (Estonia). Also, the findings are based on a relatively small number of business process modelling projects and process models (8 projects in total). The involvement of more organizations, projects and process models into the research would increase the validity of results.

Another threat to validity comes from the adoption of an a priori model that scoped the set of factors considered in the case studies. This threat is mitigated however by the fact that the a priori model has been built on the basis of success factor models created and validated by different researchers in previous work.

The data collected during the case studies was mainly qualitative. The only quantitative data collected was related to use of process models (number of model use events and their time). This quantitative data was gathered to the extent required to determine if a given process model was used in a sustained manner or not. A more in-depth quantitative analysis of actual use of process models could increase the reliability of the results and reveal more details about sustained use of process models in the organizations.

4.5 Monitoring factors in an organization

The aim of the assessment of factors, which was carried out in the course of the study, was to concentrate experience on success factors from different organizations, and to analyse which factors influence the sustained use in an organization. Most participants in the study have continually assessed the factors once a year in order to analyse the impact of activities carried out within a year in the organization. On the one hand, the framework used in the study provides a basis for concentrating the activities carried out for influencing the process documentation environment; on the other hand, it is beneficial to monitor the variation of assessments over time and to plan new activities on the basis of this. We have set the results of the assessment tables of two organizations as examples. These results reflect two most typical patterns – variations over time of an organization that is only starting with the BPM topics, and the introduction of changes in an organization that is more mature. Results have been presented on diagrams where the values of factors have been concentrated on the objects observed in the study and shown in a diagram over the years.

The first example is a state agency that, in the first assessment, had experience in process modelling primarily in the context of IT-projects. The created process models were not widely used in the organization. In Figure 15, we can see how the success factors describing the process documentation environment of the first organization have changed over time:

- Experience in process modelling and analysis project was relatively good thanks to the experience gained from IT-projects, and it has improved over time.
- Factors of objects related to the sustained use of the process model (Process Model, User, Tool) have been clearly lower in comparison with the topic of the project. This shows that process models composed in the course of the project have essentially not taken root in the organization. Positive changes over the years have occurred very slowly; focus is still primarily on specific modelling or analysis projects, at the same time, more and more models have been integrated in the daily documentation and the use of this documentation has increased considerably in comparison with the time couple of years ago.
- When more extensive introduction of the BPM was begun in 2013, in the first two years ups and downs can be detected by different objects. After three years, we can witness a clear rise in the context of all factors – activities planned in 2013 for influencing the process documentation environment and factors have begun to demonstrate influence (only!) after three years of work.
- It can be seen in Figure 15 that, in the context of technical means (BPM tool) or a smaller group of people (Process Modelling), it is easy to introduce a quick change in an organization as the circle of people dealing with these topics is quite small, and a concrete investment is enough to make the change (training, acquisition of software). At the same time, the involvement of a broader range of users and influencing the factors related to the organization's culture (Organization, User) prove to be much more difficult and changes occur relatively slowly.
-

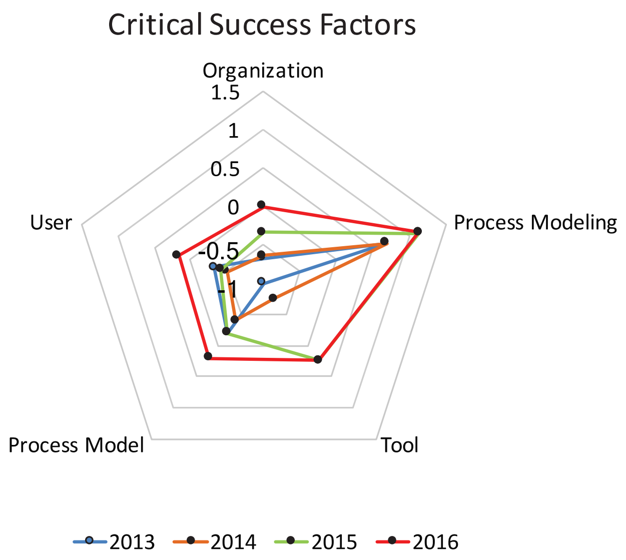

Figure 15: Success factors of the example 1

The other example is a significantly more mature organization that has actively used process models for many years, which form an integral part of the general knowledge base (Figure 16):

- In the assessment of the first year, many small details were highlighted that help to improve process modelling and update in the organization. The offered activities were introduced during the first year and the results were evident already in the second assessment one year after.
- In comparison with the previous organization, factors of objects related to the use of the process model were significantly higher. This is a clear reflection of the sustained use of the process model in the organization. We would like to make specific reference to factors related to the organization that demonstrate the fact that BPM has taken root and the process model is used actively every day.
- In the comparison of the pace of change related to modelling and the later use of the model, a clear difference can be seen – as the activities related to process modelling concern a smaller number of people and especially the modelling team, creating a supportive environment and introducing changes is relatively easy. At the same time, looking at the later use of the process model, we can see that the number of people related to changes is substantially bigger (practically the whole organization) – because of this, making and establishing changes is significantly more complex and time-consuming.

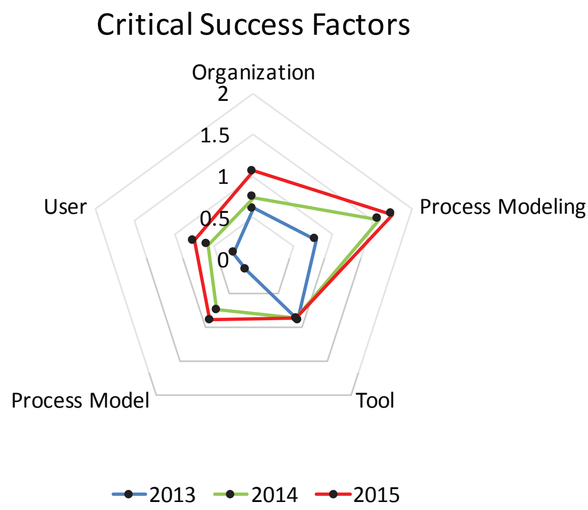

Figure 16: Success factors of the example 2

Assessment used in this study provides the organization with three important "tools" which support the assessment and monitoring of the process documentation environment, and on the basis of this, systemic change of the whole:

- highlighting and concentrating the activities related to factors by important BPM life cycle objects brings forward the steps take so far and provides a basis for planning new activities for influencing important objects;
- the grades of one year demonstrate the difference in the context of BPM life cycle objects – which objects have been addressed in practice and to what extent, and which is the result achieved from the angle of success factors;
- the comparison of grades within many years demonstrates the influence of planned activities on factors and helps to plan new changes which are necessary for improving the knowledge management environment.

All in all, we can say that such assessment and systematisation of factors creates a basis for monitoring the development of the process documentation environment in the organization and for planning the necessary changes.

4.6 Conclusion

We have proposed a model to explain the sustained use of process models and validated it on four case studies. The overall findings of the study are summarized in Figure 17. The boxes correspond to the categories of factors presented in Table 2, while arrows indicate the identified influences between factors in a category and sustained use of process models. The statements in case studies supporting each influence arrow can be found in Section 4.4.4 (cf. statements highlighted in italics). Factors have been ranked under groups of different factors in following the average of the results of ranking (participants' assessment collected in the third meeting – last column of Table 3 "Rank").

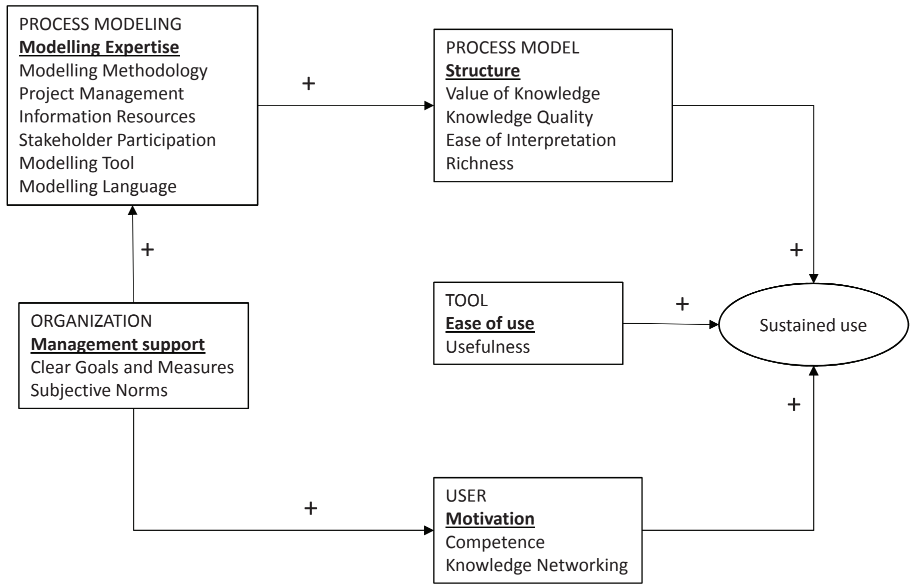

Figure 17: Direct influences between different factor groups

A notable observation highlighted by case studies is that the characteristics of process models influence their sustained use. One factor in particular that was highlighted as contributing to sustained use was the 'Structure' of the process model. The importance of structure is also confirmed by study [156] [157], where the topic of process hierarchy came up through studying the quality of a process model and the influence it exerted on process management in an organization. Also, structure is an essential component of the quality of the model and comprehensibility to the user [142].

In the 'User' category, 'Motivation' appears to be a key factor in the context of our study. Significance of motivation is also outlined in the study by Bhatt [158], where the topic was approached more widely from the angle of the behaviour of the organization.

Indication of support from the management was not surprising as the launch of such big projects needs obvious support from the management [140]. In the context of our study, indication of the impact of management on users through positive example is important.

5. EFFECTS OF MIXING TEXT AND DIAGRAMS ON BUSINESS PROCESS MODEL USE

5.1 Introduction

Business process models are a widely employed vehicle for preserving and communicating critical knowledge about business operations. A key tradeoff that business process models need to strike is that they need to be simple enough to be understood by a wide range of stakeholders, yet precise and detailed, so that these stakeholders can extract from them actionable insights for the performance and improvement of daily business operations [159].

A common approach to strike this tradeoff is to combine diagrammatic and textual components in a business process model. For example, the diagrammatic component may be used to highlight important relations between the elements of the business process, e.g. to show temporal relations between tasks [33]. Meanwhile, textual descriptions are used to provide detailed documentation about each element, e.g. steps involved in a task and business rules or guidelines relevant for its performance.

If the intended users of a process model are process managers and analysts, a wide range of details can be captured in diagrammatic form by exploiting advanced process modelling constructs, such as those available in the Business Process Model and Notation (BPMN). If, however, the intended users are process workers, i.e. employees who work on the process on a daily basis, and if the model is part of their operational knowledge base [13], it might be counter-productive to capture too many details in diagrammatic form. Indeed, process workers do not usually have the required fluency in process modelling notations to understand subtle process modelling constructs. In addition, many of the details they are looking after are very fine-grained and might affect only one task locally and hence do not affect the flow of control across tasks. These observations raise the following question: in the context of process models intended to be used by process workers, how much and what information should be presented in diagrammatic form, and how much and what information should be captured in textual form?

The aim of this study is to identify relations between the use of process models in an operational knowledge base, and their representation format (text, diagrams and combinations thereof). Specifically, the study seeks to identify combinations of text and diagrams in such process models are associated with their sustained use. In this context, sustained use is defined as the regular use of a process model by its intended users, past the project or initiative where the model was initially produced.

Importantly, the study focuses on process models that capture operational knowledge (i.e. how the process should be performed at the lowest level of detail) and are hence intended for consumption by process workers, as opposed to process models that capture tactical knowledge and are intended to be used by process managers or analysts for process improvement. The study also excludes executable process models, i.e. machine-readable process models that are intended to be used to configure a process-aware information system, such as a Business Process Management System (BPMS).

In order to address the above question, we analysed the use of process models in a large organization that maintains an operational knowledge base consisting of process models with different styles, ranging from models consisting mainly of text and tables, to models with a predominantly diagrammatic style. We analysed the mix of text and diagrams in the process models of the organization, and related this mix to their sustained use.

The rest of Chapter 5 is structured as follows. Section 5.2 lays down the theoretical background of the study by analysing previous work and deriving from it terminology. Section 5.3 presents hypotheses and variables used to test these hypotheses. Section 5.4 then presents the case study setting and data collection, while Section 5.5 discusses the findings. Finally, Section 5.6 summarizes the contribution of the study.

5.2 Related Work

Nolte et al. [31] has identified factors that contribute to the use of process models, covering both organizational factors and usability factors (e.g. perceived ease of interpretation, perceived semantic quality and satisfaction with use). Sanches-Gonzalez et al. [142] and Mendling et al. [143] have empirically analysed a number of factors that determine the understandability of business process diagrams. These and other studies have proposed and evaluated several complexity measures of process diagrams [160] such as the number of nodes, the average gateway degree and the density of the diagram. However, these studies focus on purely diagrammatic process models without taking into account textual components.

In order to improve the understandability of process models, different practical recommendations and guidelines have been assembled and validated in a number of studies [78], [84], [79]. Mendling et al. [81] outline and empirically validate seven modelling guidelines aimed at increasing the understandability of process models. The first five guidelines are specific to diagrammatic modelling notations. The sixth guideline ("use verb-object activity labels") refers to the labeling of activities in diagrammatic process models. This guideline ties up diagram and text but only in the narrow setting of task labeling. The last guideline ("decompose a model with more than 50 elements into smaller models") refers to process-subprocess decomposition and is applicable to both diagrammatic and textual process descriptions. This latter guideline is related to more general guidelines [34] for decomposing complex models and documents. Variants of this latter guideline can be found in a variety of fields, e.g. management [161], software design [4], document management [162]. Accordingly, we retain the number of elements in a model as one of the main parameters in our study.

Ottensooser et al. [11] analyse the relative understandability of purely textual vs. purely graphical process descriptions. Their results show that process diagrams are associated with higher understandability. However, their study does not consider combinations of diagrams and text in the same model. A common point between the study of Ottensooser et al. and ours is that we focus on on process models that are intended to be used by process workers during the performance of the process.

In other studies with broader scope (not focused on process models), the supporting role of diagrams in understanding textual descriptions has been highlighted: Eppler and Burkhard [33] analyse the visual representation of information in the context of knowledge management; Carney and Levin [95] study focus is on the learning aspect; the study by Larkin and Simoni [96] brings out the context where diagrams are efficient to use. These and other studies assert that interleaving text and diagrams generally enhances understandability [159]. These articles provide general recommendations for enhancing knowledge reuse, but no concrete guidelines that would be specifically applicable to business process models.

Links have also been established between various quality dimensions and usability of process models [72]. In this respect, it has been established that both semantic quality (the fact that the model reflects reality) [163], and syntactic quality (correct use of the modeling notation) [164] contribute to process model usability. In our study, we concentrate on assessing the balance between diagrams and text in a process model and its relation to sustained use.

In summary, this study differs from previous ones in that it studies how the mixture of diagrammatic and textual components in a process model relates to its sustained use. Other studies have either studied the understandability of general-purpose documents that combine visual and textual components, or the understandability and usability of diagrammatic process models taken in isolation, or compared to purely textual process descriptions as in [11]. Another distinguishing feature of the present study is that it focuses on process models that are intended for consumption by process workers. Previous studies have studied the understandability and use of process models in a broader setting, without distinguishing between process models intended for use by analysts and managers only (e.g. for process analysis, improvement or implementation) versus models that are intended to be used as a reference during the performance of a process.

5.3 Hypotheses and Variables

In this section, we discuss the hypotheses of the study in terms of relations between independent variables capturing different characteristics of a process model, and the dependent variable, namely (sustained) process model usage.

5.3.1 Hypotheses

We are interested in establishing links between variables characterizing the mixture of textual and diagrammatic components in process models, and the sustained use of these models. Accordingly, the general null hypothesis is that there is no connection between the variables characterizing the balance between text and diagrams in a model, and its sustained use.

H0. The variables of models that are used on a sustained basis do not differ from the variables of a model with a narrower scope of use.

This null hypothesis will be instantiated for each of the characteristics discussed below, each of which late gives rise to an independent variable.

Visual presentation of the tasks

Since we are interested in finding a suitable balance between diagrams and text in a process model, and given that the tasks are arguably the main elements of a process, a natural question is how many tasks should be presented graphically in a process model vs. how many should be described only as text? The aim here is to determine whether or not the presentation of more tasks in diagrammatic form increases the sustained use of a model.

H1. Process models where more tasks are visually presented (i.e. more tasks are represented as diagrammatic shapes) are more likely to be used on a sustained basis.

Visual presentation of the process hierarchy

In order to present the context of the tasks in a process, a structured decomposition is generally used [4]; this enables modellers to decompose complex objects (in our case, tasks) into smaller and simpler sub-objects. Such decomposition is carried out until objects are reached at a level of detail that is sufficient to comprehend their relationships. If the reader is given a visual representation of the decomposition [165], this may help him/her with a way of navigating in order to locate specific objects. The importance of structure in process models has been emphasized in several studies, e.g. Laue and Mendling [85]. The structure of a collection of processes is called a *process architecture*.

H2. Models that include a visual presentation of the process architecture are more likely to be used on a sustained basis.

Visual presentation of the ordering relation

In addition to being used to capture hierarchical (part-of) relations, process models are used to capture ordering relations between tasks. There is a tradeoff here between capturing these ordering relations in diagrammatic versus in textual form. Capturing ordering relations via diagrammatic constructs with clear execution semantics can enhance the understandability and precision of process models [11]. On the other hand, if all ordering relations are captured diagrammatically (including those between very fine-grained tasks, also known as *steps*), the diagrams may become overly complicated [142]. Hence, we are interested in testing the following hypothesis.

H3. Models that include a diagrammatic presentation of the ordering relations between tasks are more likely to be used on a sustained basis.

Size of the model

If a model is to be used by process workers on a daily basis, it needs to include enough details so that process workers cannot learn them all by habit and thus find value in consulting the model constantly. Hence, one can hypothesize that a model that is used on a sustained basis is likely to be larger than models that are used on an ad hoc basis. We can find a similar claim in Nolte et al. [166] where one of the factors that is found to promote reuse of process models is their (total) size (including the size of all subprocess models if any).

H4. Larger process models are more likely to be used on a sustained basis.

5.3.2 Variables and Scales

For the independent variables, we chose general variables that directly map to the four characteristics of process models discussed above. We have deliberately chosen coarse-grained scales for these variables because gathering more detailed information is prone to errors in the case of models with textual descriptions – for example, the size of the model (number of tasks) cannot always be ascertained with high accuracy for textual models as the notion of task can be subjective. Also, it is unlikely that a finer granularity would add accuracy to data analysis and to the testing of the hypotheses. Likewise, in the implementation of the insights obtained from the study, coarse-grained results are more significant.

The variables and their hypothesized relations are summarized in Figure 18.

Dependent variable – Process Model Usage

We include one dependent variable (**Process Model Usage**) in the study. The variable in question captures whether the process model has been used on a sustained basis or not. The value range of the dependent variable is:

- 0 – No sustained use – the model is not used regularly; it is potentially used by managers or analysts on an ad hoc basis, e.g. a couple of times a year.
- 1 – Sustained use – the model is used at least once per day by at least one process worker in their performance of the process, for a period of at least one year after initial creation of the model.

Variable – Task Balance

An task in a process model may appear in diagrammatic form (i.e. as an task node in a process diagram) or in purely textual form (e.g. as a step in a textual description or as an item in a checklist). To capture this dichotomy, we define a variable *task balance* as the ratio between the number of diagrammatically presented tasks and the total number of tasks in a model (incl. those in textual form). To keep a coarse granularity (cf. discussion above), we present the variable as a factor characteristic similar to the scale by Schindler and Cooper [167]:

- 1 – all tasks are presented textual form;
- 2 – up to a third of the tasks are presented in diagrammatic form (most of the tasks have been described in the form of text, important tasks are presented by process diagrams – diagrams support the reading of the text);
- 3 – up to 66% of the tasks are presented in diagrammatic form (most of the tasks have been described in the form of text – diagrams provide the basis for documentation, text supplements the diagram);
- 4 – all or close to all tasks are presented in diagrammatic form (process model is depicted in the form of a diagram – the user receives most of the information from a diagram, and the descriptions of the elements of this diagram has been added as text).

Variable – Architecture Balance

We define the architecture balance of a process model as a characteristic factor derived from the percentage of task decomposition relations (e.g. process-subprocess relations) that are captured in diagrammatic form [26]. In the definition of the scale of this variable, we further distinguish the case where decomposition relations are captured in free-text form versus the case where they are captured in textual but structured form (tables and lists).

- 1 – all or most task decomposition relations are in free-text form;
- 2 – all or most task decomposition relations are in textual form: some in free-text form and others in structured text form (table of contents has been added to the descriptions of tasks, which brings out a structure consisting of up to two levels);
- 3 – all task decomposition relations are in structured text form (a detailed table of contents has been added to the descriptions of the tasks, which brings out a structure consisting of more than two levels);
- 4 – decomposition relations are partly in diagrammatic form and partly in textual form (in addition to a detailed table of contents, a visual diagram has been added to the descriptions of the tasks, which provides a visual overview of the hierarchy of tasks, simplifies the understanding of the structure of the table of contents in the use of the process model);
- 5 – all or most decomposition relations are captured in diagrammatic form (in the use of the process model, one relies on the process hierarchy presented in the graphic form).

Variable – Ordering Relations Balance

Similarly, we define the *ordering relations balance* as a characteristic factor derived from the percentage of task ordering relations captured in diagrammatic form, following existing definitions such as the one in [9]:

* 1 – all ordering relations are captured in textual form;
* 2 – all ordering relations are captured spatially, i.e. tasks in diagrams are arranged from left to right or top-down, but no arcs are used to denote ordering relations;
* 3 – all or most ordering relations are captured via arcs;
* 4 – in addition to the above, the start and end points of the process are explicitly captured in diagrammatic form;
* 5 – in addition to the above, alternative and parallel process branches are captured, e.g. using gateways in BPMN [36].

Moderating variable – Size
Finally, we define a factor variable by discretizing the size of the model, where size refers to the number of tasks, including (sub-)processes, tasks and steps.

* 1 – 10–50 – small number of tasks, typically high-level models where, for example, a general list or sequence of tasks is presented;
* 2 – 50–100 – small-to-medium-sized models typically used to for the purpose of analysis;
* 3 – 100–500 – medium-sized models with an average level of detail;
* 4 – 500–1000 – detailed models covering a significant portion of a value chain;
* 5 – 1000+ – detailed models of end-to-end processes.

The variables and their hypothesized relations are summarized in Figure 18.

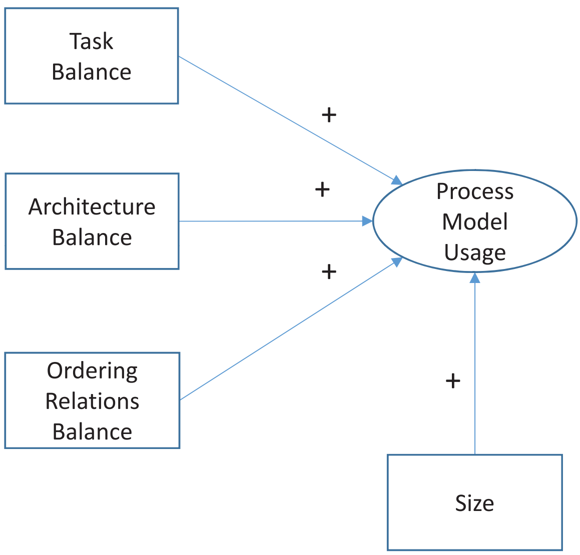

Figure 18: Hypothesized relations between variables

We note that there may be a relation between size and architecture balance, as larger process models might require deeper hierarchical decompositions to remain manageable. However, this relation is not in the scope of this study.

5.4 Case Study

This section introduces the case study conducted to validate the hypotheses. First, an overview of the context of the study is provided. Second, the data collection methodology is introduced. Finally, the findings and validity issues related to the study are brought out.

5.4.1 Context

The case study was conducted at Telia, a large European telecommunications company with business units in 17 countries. The study focused on the Estonian branch, which has around 2000 employees. Telia Estonia has implemented process management practices for over a decade and self-assesses itself at level 4 on the CMM scale [168]. It maintains process models covering all core and some support processes of the organization, that form the entire knowledge base of the organization These models are used by managers and analysts as well as by process workers. Although BPMN is the most widely used graphical process modelling notation, the company has enforced the use of BPMN in the creation of process diagrams, at the same time, there is no direct requirement to present all (especially more detailed) descriptions of processes only in diagrammatic form. Hence, models are maintained in a variety of formats, including free-text, structured text (tables, listings and checklists), free-form diagrams, BPMN diagrams and combinations thereof. This latter characteristic makes this organization suitable to test the formulated hypotheses.

The organization has been developed and managed in the process view already as of the year 2000, and process diagrams have been used as an important part of daily documentation from that time. Employees have been attending different process modelling workshops, and training, and done relevant tasks; for this reason, employees are familiar with the common elements of BPMN notation.

Process models in the case organization can be clearly divided into those that have been created for a one-off purpose (e.g. implementation of an IT solution in a particular unit) and those that have been created for wider use and indexed accordingly in their Intranet portal – the knowledge base of the organization. We excluded the first category of process models to avoid biasing the results – regardless of their size and characteristics, these one-off models are not indexed for reuse and thus they are unlikely to be used on a sustained basis.

Altogether, we gathered 48 indexed process models meant for use by process workers including: work instructions (33), models used for analysis (process models are created in the context of different BPM projects and integrated afterward into the knowledge base) (11) and high-level models intended for communication (4). We involved in the study all process models (48) that the knowledge base of the organization contains. These models are designed for usage by process workers and available to all employees of the organization in the Intranet. Models are defined at levels 4–6 with respect to the eTOM reference model [41], which is common in this industry. In the context of our research, each model falls under one area of the eTOM reference model (which covers 15 areas altogether) like for example Service Development & Management or Customer Relationship Management. Models have been created and updated during a period of about 15 years. Models describing the same area may partially overlap each other.

We did not involve those process models in the study which had been directed at a smaller circle of users in the context of specific project, such as for IT-development or process analysis; during one year, approximately 20 of such models are created. In most cases, these models are created with the help of information from the knowledge base; also, these models could serve as triggers for implementing changes in the knowledge base (for example, if errors are discovered or changes are implemented in processes in the course of a project).

A significant proportion of process models has been captured using Enterprise Architect (20). These models can be accessed using Enterprise Architect directly or via the Web view exposed by this tool, where the user of the output is able to move on the model by using links determined in the model (for instance, to move between linked diagrams in the model or to move from the diagram to the relevant textual description). 15 process models are captured using combinations of diagrams and text, where primary information is provided to the reader via text, process diagrams are included to illustrate and visualize process flow (there was about one process diagram in the context of approximately two (1–3) pages page of text). Remaining process models (13) are mainly in textual form. The size of these 28 process models was about 50 pages; documents were managed and used by employees using document management system (Livelink). All models in the study were accessible to every employee of the organization.

All models in the study have been composed by employees of the organization, primarily by process managers and business analysts. Process workers are generally consulted during the creation of most models, but they do not directly edit them. Process diagrams in the study contained the basic set of BPMN notation: task, sub-process, event (start, end), gateway, data store, data object, sequence flow, message flow, pool, lane. Process diagrams visualize the sequence of tasks, data flows and actor involvement in general; BPMN notation is not always strictly applied.

Data of the logs included:

- the user name who looked up the model;
- code of the model;
- time stamp (date and time) of entering the page.

If the same user entered into the model many times during the day, then we considered it in the variable Use as one contact. Use by process managers was excluded from the dataset (their tasks are mainly concerned with amendment and update of models); hence, only the process model usage by process workers (employees) on their own initiative is accounted in variable Use.

5.4.2 Data Collection

In collecting data, we tried to aggregate information as complete as possible on all 48 process models. In order to improve the quality of the data, we collected data on every single model from at least two people. First, we interviewed the process managers (11) who participated in the creation of the models in question and who had a stake in the respective processes. Second, we interviewed project managers (5) who have been involved in process modelling and analysis projects. Finally, we received data from the document manager who is responsible for all systems and databases related to different models. During the interviews process managers provided values for each dependent variable and for each model they had been involved with.

In cases where different interviewees gave different values for a specific variable of the same model, we assess the variable directly on the specific model (but we only three such discrepancy between the assessments occurred). In addition, we directly assess the variables of five randomly chosen models (10% of the sample) in order to test the validity of the assessments given by the respondents. Procedurally, we completed the following steps for data collection:

- organized interviews with each process manager, project manager and the document manager in the organization. During this interview, we catalogued the process models that the specific manager has come in contact with; this resulted in a list of models. We also gathered data about the independent variables defined in the Section 5.3.2 from each interviewee who acknowledged being aware of a given model. At this stage, interviewees were not aware of the hypotheses to be tested;
- after the interviews, we added up the information gathered, and highlighted the missing information and those variables of models that received different answers from different respondents;
- we organized an additional review and examination in the form of a seminar where we went through the gathered information together with the involved employees: we corrected inconsistencies and added missing pieces of information;
- we asked the document manager to provide a table indicating which models fulfill the definition of sustained, and which do not. For confidentiality reasons, we did not get access to the full logs; instead we relied on the responses given by the document manager for each model based on the definition of sustained use and minor additional clarifications.

5.4.3 Findings

We first performed a descriptive analysis of the independent and dependent variables. The distribution of the independent variables – plotted in Figure 19 – shows that all values are represented in the sample. Furthermore, 26 of the 48 analysed models were used on a sustained basis, entailing that the population is well balanced with respect to the dependent variable.

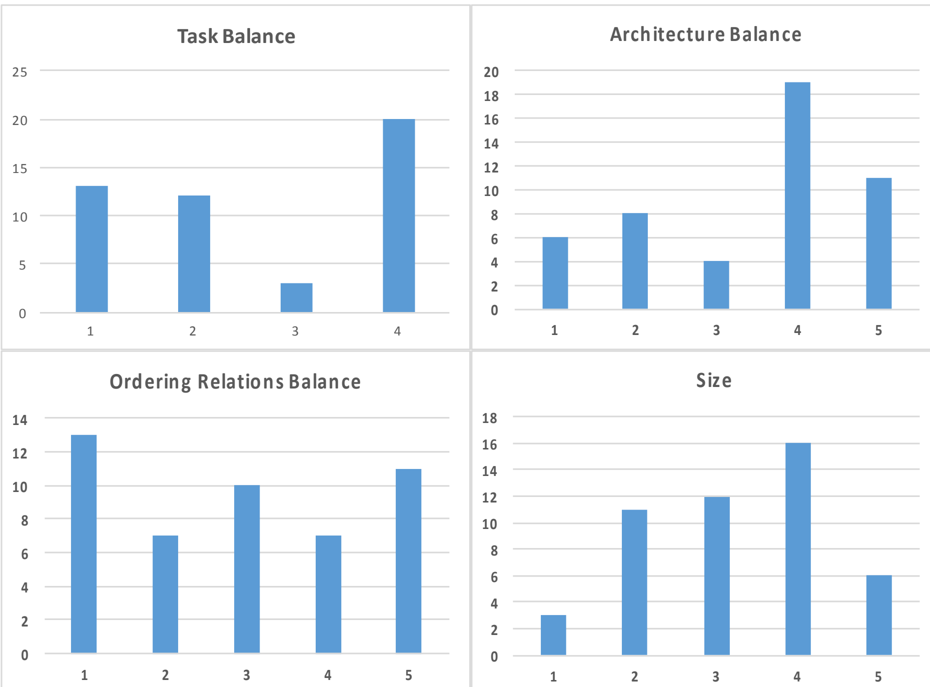

Figure 19: Distribution of variables

In order to verify the hypotheses, we applied logistic regression analysis [169]. The results of this analysis are given in the Table 4.

Table 4: Coefficients of the analysis

	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.21669	0.24237	0.894	0.3780
factor(TaskBalance)2	–0.01399	0.25389	–0.055	0.9564
factor(TaskBalance)3	0.30108	0.34885	0.863	0.3945
factor(TaskBalance)4	–0.63269	0.25814	–2.451	0.0199 *
factor(ArchitectureBalance)1	–0.39854	0.22913	–1.739	0.0916 .
factor(ArchitectureBalance)2	–0.18128	0.28419	–0.638	0.5281
factor(ArchitectureBalance)3	–0.30432	0.26944	–1.129	0.2671
factor(ArchitectureBalance)4	0.02142	0.40869	0.052	0.9585
factor(OrderingRelationsBalance)2	0.68902	0.26473	2.603	0.0139 *
factor(OrderingRelationsBalance)3	0.53492	0.25490	2.099	0.0438 *
factor(OrderingRelationsBalance)4	0.61398	0.29809	2.060	0.0476 *
factor(OrderingRelationsBalance)5	0.32102	0.37166	0.864	0.3942
factor(Size)2	0.39064	0.23198	1.684	0.1019
factor(Size)3	0.17392	0.25019	0.695	0.4920
factor(Size)4	0.68143	0.25750	2.646	0.0125 *
factor(Size)5	0.28146	0.28354	0.993	0.3283

'*' means significant correlation with p-value < 0.05

Looking at the Task Balance, a negative correlation with the sustained use is observed (t=–2.451, p=0.0199) at value 4 (more than 2/3 of tasks have been reflected on the process diagram); thus, we may conclude that if most of the processes are presented in a purely diagrammatic form, they are less likely to be used on a sustained basis.

With respect to the variable Architecture Balance, analysis did not highlight positive correlation with larger values of the variable (process hierarchy is presented in graphical form); at the same time the analysis shows a weak negative correlation (t=–1.739, p=0.0916) as regards sustained use of the model at value 1 (structure has been presented in the form of text) which indicates that the lack of visualized structure has a negative impact on the sustained use of the process model.

The link between the variable Ordering Relations Balance and the sustained use of the model becomes evident (p<0.05) especially at smaller values of the variable (2–4) – the ordering relations has been presented on the basis of simple diagrams. At the same time, it can be stated that as regards more complex diagrams (value of the factor characteristic 5 – the ordering relations described in more detail, using decision points), the analysis does not show a link.

The correlation between the size of the model and its sustained use (t=2.646, p=0.0125) becomes evident at value 4 (scale of tasks 500–1000). This indicates that larger models tend to be more likely to be used in a sustained manner. At the same time, the analysis did not show this association in case of very large models (more than 1000 tasks).

5.4.4 Limitations and threats to validity

The findings of this study should be construed in the light of typical limitations and threats to validity of a case study research. A key threat to internal validity of the study is that the number of models was relatively small. To mitigate this threat to validity, we selected a large organization with models with different characteristics according to the defined variables, as reflected in histograms of the distribution of the variables. Conducting the study in other organizations with similar or larger amounts of models would naturally enhance the validity of the results.

In the interpretation of the study results, it must be taken into account that only those process models that had been integrated into the knowledge base were included in the study – process models developed for daily use by process workers and available to all employees in the organization. In the generalization of the results, the context of the study must be taken into account (experience, size, type of the organization). Further studies in organizations of different sizes are required to enhance the generalizability.

The choice of variables and the choice of discretization of these variables is a limitation of the study. These choices were driven by our objective to identify relations between the way text and diagrams are combined in a process model, and its sustained use. We acknowledge however that many other factors play a role in the sustained use of process models. Previous studies have investigated related questions, such as the relation between organizational and usability factors and use of process models [31], the relation between internal characteristics of diagrammatic process models and understandability [160] and the relative understandability of purely diagrammatic and purely textual process models [11]. Combining these various models into a single overall model that explains sustained use from multiple perspectives is a possible direction for future work.

5.5 Discussion

The visual presentation of the ordering relations in diagrammatic form appears to be instrumental to sustained model use (H3: Models that include a diagrammatic presentation of the ordering relations between tasks are more likely to be used on a sustained basis). Here, the complexity of the process diagram plays an adjustment role – process diagrams should not be too complex, otherwise the diagrammatic representation of ordering relations has a lesser influence on sustained use.

The analysis demonstrated that larger models, where approximately 500–1000 tasks have been described, tend to be used more actively (H4: Larger process models are more likely to be used on a sustained basis). All process models cover one area in the respect of eTOM model and these areas are almost with the same size; for this reason, the differences in the variable Size comes due granularity of the model. With respect to size and granularity, users prefer to use models where information is presented at a more detailed level (levels 4–6 in the respect of eTOM model). At the same time, very detailed models of a technical nature (levels 6–7) are not used on a sustained manner.

The results also indicate that if most of the tasks of a model have been presented on diagrams, the model is less used on a sustained basis (H1: Process models where more tasks are visually presented (i.e. more tasks are represented as diagrammatic shapes) are more likely to be used on a sustained basis)). On the other hand, the analysis did not bring out a clear correlation between the sustained use of a process model and the existence of a diagrammatic representation of the process architecture (H2: Models that include a visual presentation of the process architecture are more likely to be used on a sustained basis); however, a lack of architecture (for example free-text format in the context of our study) shows a negative influence on the sustained use of the process model.

Models described in a pure text format and models with too formal structure, are not used in a sustained manner. Parameter Size pointed out that models used in a sustained manner are usually with medium granularity. These two findings highlight the middle area in Process Documentation Cube (Chapter 3) in the view Structure-Granularity – models located in the area are most commonly used in a sustained manner.

A summary of the above observations is given in Figure 20.

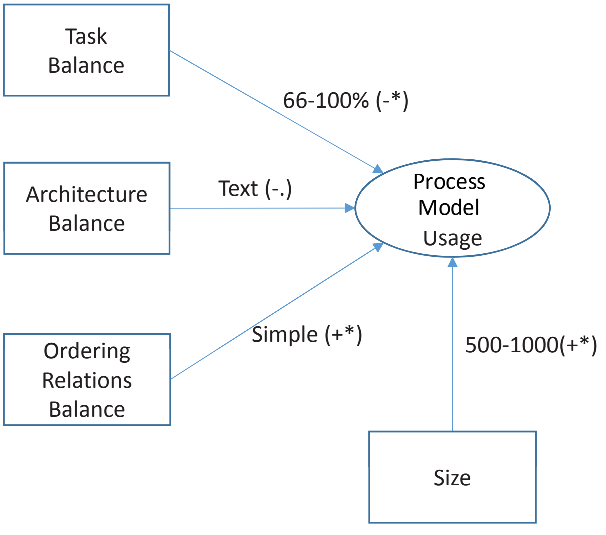

Figure 20: Results of the study

5.6 Conclusion

In conclusion, we can state that a typical process model that is used on a sustained basis as a knowledge base in the organization is one where the key tasks and their ordering relations are captured in diagrammatic form, while further details are left in explanatory (possibly structured) text. It is important that diagrams would provide the user who is reading the information with a process logic on a general level to which descriptions of details in the form of text will be given. The key observation here is that for smaller models, the diagrammatic representation of ordering relations between tasks is associated with more sustained use, but this does not necessarily hold when the models become larger.

A second insight is that when it comes to capturing the process architecture, the use of text to complement diagrams does not seem to play a role in the sustained use of the process model. Process hierarchy plays a vital role during process modelling, where graphical representation of the structure facilitates the decomposition of tasks; process workers are looking for a general and simple table of contents to understand the general structure of the process model.

In future work, we plan to extend the study to cover other organizations. This should enable us to extend the number of process models in the study and thus to enhance the validity and scope of the findings. Also, as stated in the limitations of the study, there are several other factors that potentially affect the (sustained) use of process models, including factors related to the type of process being captured (e.g. customer-facing versus backend processes), as well as organizational and usability factors. A direction for future work is to combine the findings of the present study with those from other studies referenced above, in order to build a broader model of (sustained) process model use. Validating such a broader model would require larger datasets, and hence this second direction of future work should go hand-in-hand with the first one.

6. CONCLUSION

In conclusion, the three core studies included in the thesis (Chapter 3–5) and its preceding theoretical summary (Chapter 2) provide a framework for analysing the use of process models in an enterprise and for planning changes, especially if the aim is to increase the use of process models and to extend the circle of their users. The thesis brings out factors and parameters that should be kept in mind when process models are intended to be used in a sustained manner in the organization. The presented tools can be applied when launching systematic process modelling efforts in new organizations, or when planning improvements to existing process modelling efforts.

Good balance between organizational settings (factors related to Organization, Users and Process modelling) and technical parameters directly related to the knowledge base (factors related to Model and Tools) is necessary when the sustained use of knowledge base is substantial for the organization. The efforts needed for influencing different factors and time needed for changes afterward vary considerably. For this reason, it is not an easy task for an organization to develop critical success factors of sustained use in the manner where investments to improve and develop one factor would be supported and accelerated by the other success factors and not opposite. If the sustained use of the knowledge base is set as an objective for the organization, then the success factors presented in the structured form in Chapter 4 bring out the important issues to keep an eye on and develop as a single entity.

Presenting the process hierarchy of the model in a structured form has a positive impact on the sustained use of the model. One has to be careful in adding structured components into the descriptions of processes – it is not easy for the process worker to understand the structure(s) and obtain essential information from the diagram. Thus, the balance between pure text and diagram has to be "shifted" toward the text, especially in the context of bigger process models, where the amount of information is large and the process diagrams tend to be voluminous and complicated. If a significant part of the information is presented on a diagram and less information is given via text (you have to "read" the diagram first), then the model is rather appropriate for technical people, and does not serve as a part of knowledge base for process workers.

The findings of the three studies should be construed in the light of typical limitations and threats to validity of case study research. A key threat to internal validity of the studies is that the number of models and organizations was relatively limited. On the other hand, the set of organizations involved in the case studies is rather diverse, covering both the public and private sector, different business sectors, and different sizes and levels of process modelling experience.

An important limitation of the case studies results from the fact that the studies have been conducted in one single country – analysis and assessment methods offered in the study have not been tested in various cultural and economic contexts. This must certainly be taken into account when offered methods are used or generalisations applied in another country having a significantly different economic or cultural context. Implementation of the studies in different countries in the future would give an international dimension to the results, and would help to take into account differences in culture and differences in the markets and regulations in which the organizations operate.

There is an important limitation concerning the two first studies (Chapters 3 and Chapter 4), namely that these are of an exploratory nature and the observations made in them lack any statistical significance. There are quantitative data and analysis involved in the third study described in Chapter 5, but the research is restricted to a single organization. A direction for future work is to conduct further quantitative studies in order to refine the observations made, particularly in the first two studies.

KOKKUVÕTE (SUMMARY IN ESTONIAN)

Protsessimudelite struktuur koosmõjus mudeli kasutusega

Aristoteles on öelnud, et üks pilt on väärt tuhat sõna. Kui eelnev mõttetera on esitatud info edastamise kontekstis, kus lisaks tuimadele faktidele soovitakse anda edasi ka emotsiooni ja tunnet, siis kuidas toimib sama lause just nimelt tuimade faktide edastamisel?

Järjest enam kasutatakse organisatsioonides teksti kujul esitatud kirjelduste juures oluliste faktide ja seoste väljatoomiseks diagramme. Kui diagrammide kasutamine igapäevaste reglementide ja seaduste juures on veel harjumatu, siis protsesside kirjeldamisel on see pigem normiks. Paljudes uuringutes on võrreldud, kuidas suudavad erinevad kasutajagrupid haarata olulist infot kirjeldustest, mis on esitatud kas teksti või diagrammi kujul. Samas on vähem tähelepanu pööratud teksti ja diagrammide koos kasutamisele ja seda just selliste kirjelduste juures, mida soovitakse organisatsioonis laiemalt kasutada. Antud töö eesmärgiks oli uurida, millises tasakaalus peaks olema organisatsiooni kirjeldavas dokumentatsioonis diagrammi kujul esitatud selgitavad joonised ja teksti kujul kirjeldused, et see leiaks laiemat kasutust. Analüüsiti, kuidas praktikas olulise informatsiooni esitamisel, diagramme tekstiga kombineeritakse ja millised faktorid soodustavad organisatsiooni kirjeldava dokumentatsiooni laialdasemat kasutust.

Esimeses uuringus analüüsitakse teadmiste kajastamist erinevates organisatsioonides. Selleks on uuringu autor välja töötanud spetsiaalse töövahendi – protsessikuubi, mis toob visualiseeritult välja, milline on organisatsiooni kirjeldav dokumentatsioon, sh millise struktuuriga see dokumentatsioon on ja millise detailsuse tasemel see katab organisatsiooni erinevaid tegevusvaldkondi. Protsessikuup on hea töövahend teadmiste haldamisega seotud muudatuste planeerimiseks organisatsioonis. Samuti annab protsessikuup lihtsa struktuuri, mille baasil võrrelda omavahel erinevate organisatsioonide teadmiste haldamist.

Teises uuringus analüüsitakse üksikasjalikult protsessimudeli kasutamist mõjutavaid edufaktoreid. Eelnevatest uuringutest, milles on teadlaste ja praktikute poolt käsitletud protsessimudeli loomise ja kasutusega seotud edufaktoreid, on autor koondatud olulised edufaktorid üheks tervikuks ja toodud need protsessimudelite laiema kasutuse konteksti organisatsioonis. Loodud edufaktorite mudelit on rakendatud erinevate organisatsioonide konteksti hindamiseks ja analüüsitud tulemusi koos protsessimudeli reaalse kasutusega organisatsioonides.

Kolmas uuring keskendub protsessimudeli struktuuri kajastatavatele parameetritele ja analüüsitakse nende mõju mudeli kasutusele organisatsioonis. Praktikas viidi läbi uuring telekommunikatsiooni ettevõttes, kus on aastate jooksul loodud erinevas formaadis protsessimudeleid ja kellel on pikaajaline mudelite kasutuskogemus. Rakenduslik uuring tõi välja, et laialdast kasutust organisatsioonis leiavad protsessimudelid, kus diagrammiga tuuakse välja keskmise detailsusega tegevuste järgnevus ajas ja detailsemal tasemel tegevused esitatakse teksti kujul. Diagrammide ja teksti kombineerimine suurendab protsessimudelite laiemat kasutust – tekst ilma joonisteta või detailsed joonised ilma pikema tekstilise kirjelduseta mõjutavad negatiivselt protsessimudelite laiemat kasutust organisatsioonis. Uuring näitas, milline on organisatsioonis laiemat kasutust leidnud protsessimudelite tasakaalupunkt diagrammide ja neid täiendava teksti vahel.

APPENDIX A – FACTORS OF SUSTAINED USE

Group	Factors	Definition
Organization	Management Support	The level of commitment by senior management in the organization to the BPM activities in terms of their own involvement and the willingness to allocate valuable organizational resources.
	Clear Goals and Purposes	The clarity of goals and purposes of the BPM initiatives in the organization.
	Subjective Norms	The perceived opinions of a person or group whose beliefs may be important to the individual about process model re-use.
Process Modelling	Modelling Expertise	The experiences of process modellers in terms of conceptual modelling in general and process modelling in particular.
	Stakeholders Participation	The degree of input from users in the design, approval and maintenance of the models.
	Information Resources	Availability of information during the project.
	Project Management	The management of the process modelling project, including defining the project scope, aims, milestones, and plans.
	Modelling Methodology	A detailed set of instructions that describes and guides the process of modelling.
	Modelling Language	The grammar or the 'syntactic rules' of the selected process modelling technique.
	Modelling Tool	The software that facilitates the design, maintenance and distribution of process models.
Process Model	Richness	Availability of necessary information in the process model.
	Sematic Quality	The degree of correspondence between information conveyed by a process model and the domain that is modelled.
	Value of Knowledge	The degree to which a person believes (re-)using a particular process model will help to achieve the intended goal.
	Structure	The degree to which a person believes that finding necessary information from the model is simple.
	Ease of Interpretation	The degree to which a person believes that interpreting a process model would be effortless.
Tool	Ease of Use	The degree to which a person believes that the use of modelling software for using a process model would be easy.

	Usefulness	The degree to which a person believes that using a modelling software will be effective in using a process model.
User	Competence	The amount of knowledge the users have of the modelled domain and the use of the process models.
	Motivation	Using a process model for no apparent reason other than the task of using it, e.g. to gain knowledge of a process.
	Knowledge Networking	Users knowledge about the organization (processes) and willingness to share it.

APPENDIX B – GLOSSARY OF TERMINOLOGY

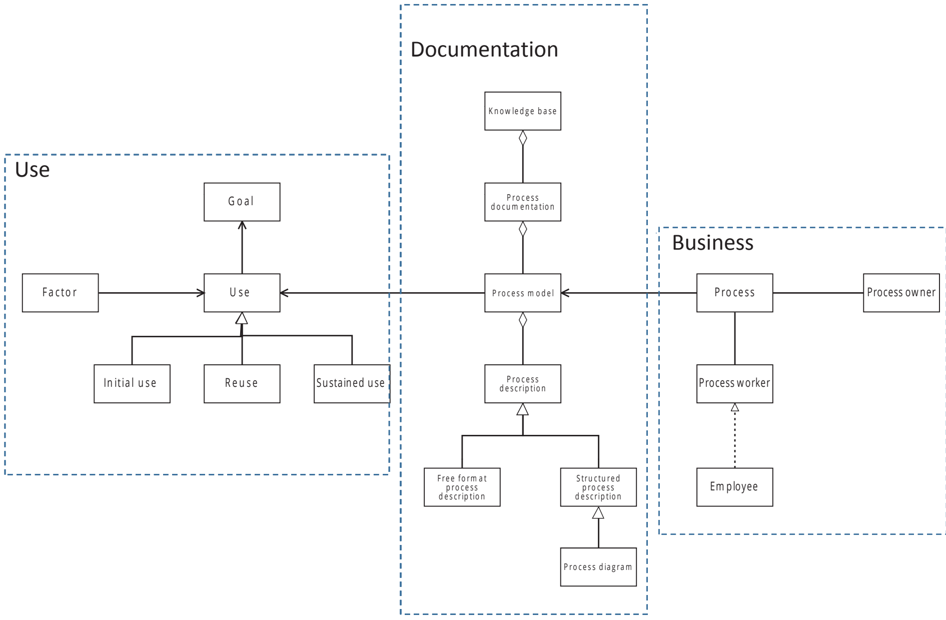

Figure 21: Terminology used in the thesis

- (Business) Process – *a collection of activities and inter-related events that lead to an outcome that is of value to the business.*
- Process worker – a *person implementing (some) activity of the process during the process execution.*
- Process owner – *a person who is responsible for the process development.*
- Process documentation – *facts in the written form about the processes of the business.*
- Process model – *an abstract representation of the processes of the business.*
- Process description – *an abstract representation of a single process of the business.*
- Free format process description – *process description where the structure of activities is not highlighted.*
- Structured process description – *process description where the structure of process activities is highlighted (visualized)*
- Process diagram – *visualized process description where the sequence of activities is highlighted.*
- (Process) Knowledge – *facts, methods, principles, techniques, etc. which the actor should be familiar with in order to implement a single process and attend the process as a whole.*
- Knowledge base – *knowledge that has been codified, captured and accumulated with the aim of communicating it to different people and to use it for business management.*
- Explicit knowledge – *knowledge that has been articulated and recorded in writing.*

- Implicit knowledge – *knowledge that can be articulated and recorded in writing, if necessary.*
- Tactic knowledge – *knowledge that cannot be articulated. Tactic knowledge can be presented through explanations and descriptions, supporting the understanding.*
- (Process model) Goal – *pre-defined purpose(s) why the process model is created and used for.*
- Process model use – *usage of the process model for defined purposes (goals).*
- Process model initial use – *usage of the process model for the purpose it was initially created for.*
- Process model re-use – *usage of the process model again after the initial use. The goal and purpose of the use could be different from initial use.*
- Process model Sustained use – *regular process model re-use by business people (process workers). The goal of the usage is to grasp the knowledge on the process.*
- Factor – *prerequisites and interaction of components around process model usage, which are needed to achieve the defined goal.*
- Business Process Management – *a body of methods, techniques and tools to discover, analyse, redesign, execute and monitor business processes.*

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