Semantically Standardized and Transparent Process Model Collections via Process Building Blocks

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***Abstract*—Process model repositories management is a complex endeavor including modeling and publishing challenges. Existing modeling notations like BPMN or EPC are not able to cover the requirements induced by the volumes of such process model collections (PMC). The modeling technique proposed in this work addresses these requirements and enables organizations to efficiently manage their respective PMC. In fact, the proposed notation based on process building blocks allows for the efficient handling of PMC of any size. Its integrated structure of building block based process models combined with the concepts of layers, attributes, glossaries, reference models, and variants makes it a universal yet semantically standardized process modeling technique. The conceptual definition of the modeling technique and a prototypical instantiation and implementation are introduced. The practical applicability of the technique is justified through an evaluation in practice.**

Business Process Management, Process Modeling, Process Model Collections

I. Motivation

Business process modeling (BPM) is a fundamental requirement in most management and IS projects [14]. A lot of companies have undertaken such an initiative for the purpose of business reorganization, certification, human resource planning or traditional software engineering [6]. The more complex the environment is, the more business processes models it contains [12]. In addition to process models, organizational charts, and a multitude of various additional documents related to the process models are created during BPM projects. All these artifacts form so-called process model collections (PMC), which according to [8] are being of great attention among researchers nowadays.

The most common modeling notations that are used for the task of process modeling are Flow Chart Diagrams, PetriNets, Integrated Definition for Function Modeling (IDEF0), Event-driven process chains (EPC), Unified Modeling Language, (UML), Business Process Model and Notation (BPMN). These existing modeling notations are subject to limitations, which have been criticized for different reasons by practitioners and researches in the field of BPM [3], [22], [1]. These limitations include a lack of standardization [24], which again imposes challenges on reusability, collection organization and variant management. The difficulties of managing PMC are therefore partly accounted for by the modeling language used to create the process models.

Besides the research endeavor conducted there are still open issues to be addressed [8], such as querying, mining, refactoring, re-use, similarity search, merging, variant management and collection organization. In the following, we will focus on the areas of reusability, because it is a fundamental idea of all modeling efforts, and follow up on ideas of collection organization as well as variant management. We will further discuss these areas from the perspective of a proposed process modeling technique, which is to be understood as a combination of a modeling notation including syntactical rules and a complementing modeling tool facilitating the application.

Therefore, the goal of this paper is to address the above-mentioned problems by answering the following research questions:

- *RQ1: How can the problem of organizing process model collections, including such aspects as variant management and storage of supporting model information, be resolved with the help of a modeling technique?*
- *RQ2: How can a modeling technique support the re-use of process models within a process model collection by semantic model standardization?*

The remainder of the paper is structured as follows. In the second section a literature review on the existing problems in two areas of BPM and PMC is carried out and their interrelations are highlighted. Our research method is presented in section three. In section four the conceptual model of the proposed modeling technique is introduced. Section five is devoted to the presentation of a prototypical implementation and evaluation of the modeling method. The paper is concluded within section six with the discussion of the findings and outline of open issues.

II. Related Work

The problems of BPM can be classified into 3 groups in terms of their occurrence before, during and after the conduction of process modeling projects [24] as follows:

- *Before* process modeling: as most of the existing modeling methods are not intuitive, process modelers as well as process model users have to learn and understand the selected process modeling language before starting a BPM project [24].

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- *During* process modeling: The most common techniques like Flow Charts, PetriNets, IDEF0, EPC, UML or BPMN allow for a high degree of freedom during modeling. They do not provide naming conventions, or standardized levels of modeling abstraction. As a result the created models differ greatly if several specialists are involved in the modeling process [3].
- *After* process modeling: Because of the high degree of freedom, the resulting process models are complex and their semantic is not standardized. They are therefore hard to analyze and re-use. In most cases, proceeding activities are a tedious manual task, in which expensive consultants have to be involved. [4]

In addition to this classification, a global Delphi study conducted by Indulska et al. (2011) identified the most influential current issues and future challenges in BPM. The following issues are among the most significant ones according to the opinion of practitioners and researchers [14]:

- lack of standardization of modeling notations, tools and methodologies;
- model management problems, i.e. publication, version, variant, or release management;
- absence of clear definition of modeling level of detail;
- lack of identification of abstraction levels;
- need for establishing process modeling expertise and collaborative modeling.

Other issues are related to the complexity management of process models as processes with a high number of elements can cause comprehension problems in such activities as model validation, maintenance and utilization [16], [17].

Regarding PMC, there are several more tasks to be considered such as querying of process models, similarity search, variant management, merging, mining, refactoring, re-use, collection organization, and repository technology [8]. Due to the BPM issues identified above, in particular huge number of process elements, high degree of freedom for modelers and absence of standardized semantics, most of these tasks and especially the model re-use and process model collection management are problematic.

III. RESEARCH METHOD

For developing a modeling technique as presented in this paper, design science research methodology (DSRM) is applied. In the area of design science (DS) research, there is a variety of concepts of how to conduct a DS endeavor. They mainly differ in the role, design theories take over in the understanding and definition of DS. On the one hand, there are notions in which design theory plays minor or even no role at all. For example, March & Smith [19], Hevner et al. [11] and Benbasat & Zmud [5] consider the IT artifact as the core research object of information systems research. On the other hand, there are notions in which the theory of how to design the IT artifact is considered as the main research objective along with the IT artifact itself. For example, Walls et al. [23], Gregor & Jones [9] and Iivari [13] propose a differentiation between the theoretical design of an IT artifact and its concrete implementation, as well as the relationship between these two aspects. Other authors like Kuechler & Vaishnavi [15] identify a mutual relationship between kernel theories and design theories saying that kernel theories can influence DS as well as they can be re-influenced by DS results.

For the purpose of this work, an overemphasizing of the role of theories is deemed not beneficial. Therefore, the notion of DS proposed by March & Smith [19] which is taken up and refined by Hevner et al. [11] is chosen as a research method in this work. According to Hevner et al. [11] the design science research process can be presented as a cycle with five main steps (Fig. 1). In order to specify the problem domain we have conducted a literature review, which revealed a number of deficiencies in the area of PMC and served as a basis for solution objectives definition. The design phase of DSRM was fulfilled by concept creation, presented in the following section of the paper. Demonstration of the result is achieved through prototypical implementation of the modeling tool. Evaluation is performed by applying the created artifact in two business modeling projects. Finally, as design is inherently iterative according to DSRM, new requirements were identified for the artifact improvement after the evaluation phase.

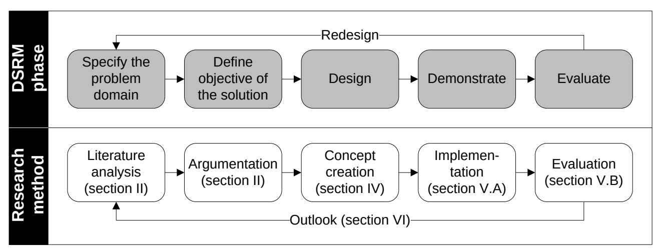

Figure 1. Research methodology

IV. CONCEPT OF THE MODELING TECHNIQUE

The main research artifact is a conceptual model based on several rationales, which are depicted in the following subsections.

A. *Layers*

In order to address the challenge of process complexity it is common practice to define layers of abstraction. The emerging question is how many layers are reasonable to support an adequate fit between necessary detailing of the process steps and constraining the amount of process information in one model with respect to usability and readability.

The most adequate amount of layers varies with respect to the modeling purpose of the modeling project. A workflow management system preparation project demands a higher level of (technical) detail in comparison to a management-oriented process modeling project. Hence, the challenge is to conceptualize a layer architecture which is able to meet the requirements for, e. g., both of the aforementioned scenarios.

B. Attributes

Despite the possibility to use the layers of abstraction, the here conceptualized technique proposes attribution as a mean to complement the process models with in-depth information on all process layers where applicable. By extending the process models with attributes, the challenge of complexity can be overcome more easily. Attribution reduces the need for sophisticated branching concepts for the control flow of the processes. Via the possibility to use different attributes on the distinct layers of abstraction, the aforementioned modeling purpose can be supported more easily. Hence, the concept of attribution fosters readability due to complexity reduction and expands the area of application due to the possibility to append attributes on any level.

Furthermore, manageable process attributes are a prerequisite for process analysis and reporting functionalities.

C. Glossary

Existing modeling techniques allow for a high degree of freedom in both syntax and semantics. These degrees of freedom also allow the modelers to arbitrarily label process elements, such as events and functions in EPC or BPMN.

Empirical studies verified that the terms used in modeling can vary heavily, especially, when developed timely, personally and regionally distributed [10]. On a word-based view, these problems are mainly caused by synonyms. As process element labels are normally composed of multiple words, the phrase structure of these words may also cause naming conflicts. It has been shown, that even when limiting the number of words to two, there are more than 20 different phrase structures being used by process modelers [7].

These issues, both on word and phrase structure base are called naming conflicts [2]. The re-use of models flawed in such a way is problematic, as they increase the complexity of the model and are thereby much harder to understand by the model users. Moreover, automated processing and analysis of the models is complicated or even impossible.

The key to prevent naming conflicts is standardizing the choice of words and the phrase structures to use before modeling and enforcing these standards during modeling [7]. Similar to the simple syntax our modeling technique strives for the simplest structures available to foster semantic standardization. Therefore, only a simple verb-object label is allowed for the phrase structures. These have proven to be understood better than all other phrase structures. [20] Within the process modeling context the verbs and objects can be interpreted as activities and business objects.

Standardization before modeling is achieved through a glossary, which is composed of several business objects. These business objects are again related to all activities, which results in a specific instantiation of the verb-noun phrase structure. The free definition of business objects and activities allows the modeling technique to be customized for any modeling scenario. This procedure is therefore chosen over the use of existing catalogues such as the MIT process handbook, although it requires more initial work [18].

The standardization is enforced during modeling, since all modeling processes have to be related to at least one glossary. Every process element is then labeled by linking the process element to one activity-business object combination specified in the glossary.

D. Reference Models

Besides the incorporation of the before mentioned rationales into the modeling technique, reference models are proposed to further enhance model creation. They allow simple and efficient model creation, since their reference character enables the modeler to easily adapt the model to his or her needs. Moreover, reference models foster models of high quality w. r. t. their best or common practice character. Furthermore, reference models facilitate storing, relating and finding the models by providing a frame which structures the process model collection in an enterprise.

E. Variants

There are several scenarios where one outcome of a process is achieved by different process activities. This often leads to complex process models, since they take a range of possible circumstances into account in the sense of additional model components. A smart way to bypass this driver of complexity is to define several variants of one process. By this mean, the process model itself often remains simple with respect to branching and model elements but therefore the amount of simple model variants is increasing. It is a trade-off between complex models and several variants of one process model. Within the proposed concept, a new model variant is created, whenever the incoming and outgoing information of the process is the same, but at least one main process activity is different from the standard procedure.

V. Prototypical Implementation and Evaluation

In this section, the prototypical implementation of the modeling technique proposed in the preceding section, is described. Moreover, an evaluation of the resulting tool in two medium sized enterprises is presented.

A. Implementation

Based on the conceptual model proposed in the preceding section, we have implemented a modeling tool prototype (Fig. 2) which fulfills all the aforementioned requirements. It is a web application based on the programming framework Ruby on Rails which follows the model-view-controller paradigm [21]. Therefore, it provides an elegant solution to separate the underlying data storage, the business logic and the presentation of the data. As the underlying database structure is easily exchangeable, the tool is able to be utilized in most scenarios and organizational IT infrastructures. Moreover, to facilitate an efficient and effective creation as well as utilization of the process models, the user interface for modeling as well as presentation of the models is designed to be highly intuitive also for non-process modeling experts. This is even enhanced by the use of JavaScript which is a client-side programming language fostering asynchronous handling of user input. Thus, irritating reloads of web pages are contained in the prototype.

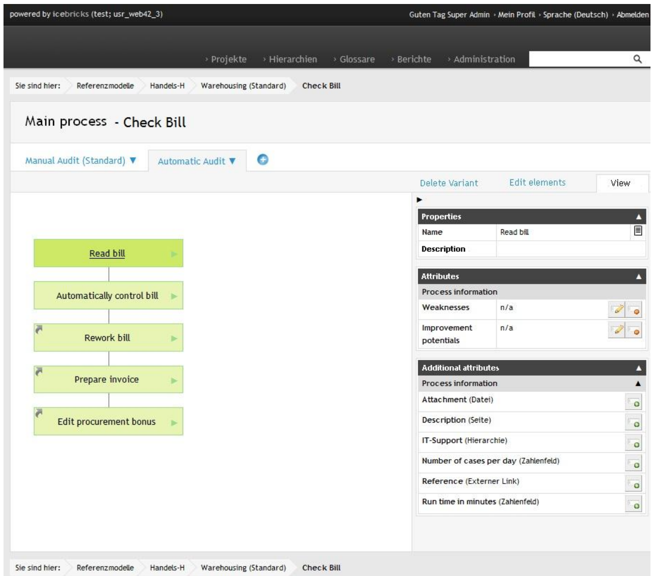

Figure 2. Main process view in the prototype.

Within the conceptual model, a layer-architecture is described as a cornerstone for the modeling technique to be implemented. Within the prototype, this layer-architecture is realized as four-layer architecture. It consists of the layers process framework, main processes, detail processes and process building blocks (PBB) (Fig. 3). On the first layer, a *process framework* provides the modelers and model users alike with a process overview respectively process landscape comprising all relevant main processes within the depicted organization ordered by e. g. functional areas. The elements of the process framework are further specified on a more detailed level in the *main process layer*. Here, the main process steps are described in order to give a rough overview about the activities usually carried out during this process in the respective business area. As an example the main process “Check Bill” is shown in figure 2. To handle parallel steps, branching methods are supported by design on this layer. Each of the main process steps is further refined by a detail process on the *detail process layer*. Like in the superordinate layer, branching methods are provided on this layer to handle parallel activities. Every modeled element on this layer is represented by a so called process building block. These PBB are defined in detail on the fourth and most detailed layer. Here, the information about the atomic activities of the depicted processes can be provided. For example, attachments like videos, documents, hyperlinks, wiki pages, etc. are supported.

According to the description in the conceptual model, the prototype features attribution on each of the four model layers. Here, process-enhancing and additional information can be provided for each of the model elements on each layer. The attributes can be specified by the administrators of the tool and by providing administrators with the possibility to specify the concrete attributes themselves, the tool allows for utilization in any organization and business area. In the example in figure 2 two attributes were defined for “Read bill” activity of the main process: weaknesses and improvement potentials.

Corresponding to the utilization of a semantic modeling approach postulated in the conceptual model, a glossary is implemented in the prototype. With it, the aforementioned naming conflicts are contained. The concrete implementation in the tool allows for the creation of glossaries in which business objects and activities can be maintained. Moreover, an assignment of activities to business objects assures that only correct combinations can be assigned to process elements. The usage of the glossary and the abovementioned four layer architecture of the prototype are aligned as well. On the process framework layer, the elements – which are the main processes – can be assigned to a business object. On the subordinate layers – main processes and detail processes – the elements – detail processes respectively PBB – can be assigned a predefined phrase structure of a business object along with an activity. By this, modeling conventions are adhered and costly refinements or corrections are avoided.

Eventually, the usage of variants is facilitated within the prototype. On the main process and detail process layers different variants can be created whenever necessary. In figure 2 there were defined two variants of “Check Bill” main process: manual audit and automatic audit. The last three activities in the exemplary main process are the same for both variants and therefore are modeled only once in the standard variant (“Manual Audit”) and afterwards inserted as references in “Automatic Audit” variant.

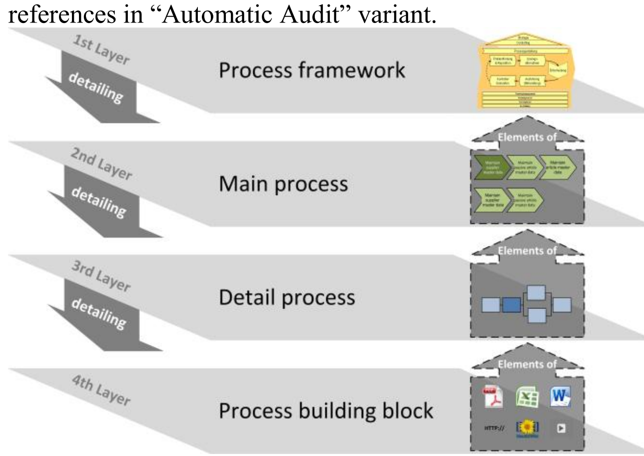

Figure 3. Layer concept of conceptual model.

B. *Evaluation*

The prototype has been evaluated in two process modeling projects. The characteristics of the companies, whose processes were modeled, are shown in Table 1. Although their characteristics differ, both companies are archetypical medium sized companies without a documented process landscape. As small and medium sized companies constitute the majority of all companies worldwide, the cases at hand are good examples for many process modeling projects to be conducted with the prototype in the future.

The first case is a business process reorganization project, which was conducted as the preparation for a consecutive ERP selection procedure. The project was structured in three steps, namely as-is process modeling to document the process landscape of the company, and two interrelated phases of to-be modeling and ERP selection to align both IT and infrastructure. All steps were conducted by a consulting company with the help of the prototype.

During the as-is modeling process, the consultants created the process models on the base of interviews with employees of the target company. As the company had not undertaken any modeling activities before the project, the processes were designed on the base of a reference model for processes in retail. Subsequently, the to-be processes were created in collaboration with all stakeholders. To support the to-be modeling phase, the prototype was customized with the attributes for detailed process element description, leading IT system, process owner, process executive, process relevance and importance of the process. Furthermore, examples of process related business documents like Excel files or scans of paper based documents were added to the processes. When engaging the as-is modeling phase, attributes for weaknesses, suggestions for improvement and optimization potential were added. In the last phase, the process models were annotated with attributes to document requirements for the new ERP software. The glossary for the process element labels was initially created before the to-be modeling phase and consecutively enhanced through the interviews. Re-use of the process models turned out to be simple, as small changes to the attributes were sufficient to re-use models created during different project phases.

TABLE I. OVERVIEW ON THE EVALUATION CASES

	Case 1	Case 2
Domain	Retail	Warehousing
Articles	~20.000, sports and fashion	~2.500, promotion material
Employees	>1.600	~250 worldwide
Customers	B2C	~6000, B2B
Modeling purpose	Process reorganization, ERP selection	Process documentation, preparation of software tests, knowledge base

The second case is a process documentation project that consists of an as-is process modeling phase. The project models will be used as a knowledge base for the company's employees and support the creation of test cases for an update of the ERP software. Like in case one no processes were documented by the company in advance and the processes were developed on the base of retail reference processes and interviews. The prototype was customized with the attributes for detailed process element description, process owner, process executive, SAP transaction codes for the test cases and links to the company-Wiki for knowledge management purposes. Analogue to case one, the glossary was enhanced consecutively during the interviews.

Although the two companies and the reasons behind the modeling projects differ significantly, the prototype and the proposed modeling technique could adapt well to both scenarios. The process modelers deemed the four layer modeling architecture well suited for the task at hand. They especially favored the simple syntax of the modeling notation and the alignment of modeling purpose and modeling technique through attributes. Glossary creation, in contrast, was carried out with reservations. The reservations were however dissolved for the most part during later stages of the project, when major renaming could be executed centrally in the glossary.

The results of the evaluation cases are promising, as they attest the modeling technique to be applicable in practice. All project stakeholders directly involved with the process models judged the collection organization support of the tool to be sufficient. Re-use of the process models turned out to be simple, as the tool could be adapted to different modeling purposes by small changes to attributes and glossary. The two aims of supporting collection organization and re-use of process models have therefore been reached.

VI. CONCLUSION AND OUTLOOK

A solution to the above stated research questions is presented in this work in form of a modeling technique which is based on a multi-layered process structure and the idea of semantic process building blocks. The proposed technique is generic with respect to the management of arbitrary PMC by allowing the technique to be tailored to the specific modeling purpose via attribution. On the one hand, the multi-layered structure allows modeling of business processes for companies of any size and from any business area. It enables efficient management of the resulting process model collection and includes features for variant management. On the other hand, the semantic building blocks in combination with a glossary allow the technique to create strongly standardized models. By adding extensive attribute support, flexibility regarding the modeling purpose is preserved.

With regard to an outlook, two aspects are in the focus of future research concerning the proposed modeling technique. On the one hand, further utilization of the attribution incorporated by the modeling technique is desirable. Here, especially the conceptual development and later implementation of elaborate analysis techniques and functionality is on the agenda. On the other hand, an in-depth evaluation of the prototype has to be carried out. While the two exemplary case studies have initially shown that the rationales seem to be valid, further validation will have to prove that to an even higher extent.

All in all, the concept of the modeling technique proposed in this paper and its prototypical instantiation have been validated by the evaluation of the prototype in two modeling undertakings. Thus, the requirements and research questions imposed by the challenges addressed in this work are met.

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