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**Pattern-Based Semi-Automatic Analysis of Weaknesses in Semantic Business Process Models in the Banking Sector**

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# PATTERN-BASED SEMI-AUTOMATIC ANALYSIS OF WEAKNESSES IN SEMANTIC BUSINESS PROCESS MODELS IN THE BANKING SECTOR

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## Abstract

*As banks have realized the need to look on their business in a process-oriented way, they have been engaged in numerous business process optimization or even reengineering (BPR) projects in the last decade to make their organizations more efficient. However, the success of BPR projects in banks varies significantly and it remains a challenge to systematically discover weaknesses in business process landscapes. In particular, automatic semantic analysis of business processes for different types of weaknesses (i.e. media breaks, redundant consistency checks, or missing or inconsistent information) is yet in its infancy. Value from business process modeling can, however, only be unveiled when time-consuming, mostly manual business process analysis is performed and results in business process optimization. In this paper we develop a methodology for semi-automatic analysis and detection of weaknesses in semantically analyzable business process models. We argue that this contributes to systematically identify possible weaknesses in process models more efficiently and more effectively than manual analysis.*

*Keywords: Automatic Business Process Analysis, Semantic Business Process Models, Process Weaknesses, Business Process Optimization, Business Process Reengineering.*

## 1 INTRODUCTION

Process models have been established as a broadly applied instrument in business process management. Therefore, researchers have developed more than two dozen modeling languages for the formal representation of business processes since the arrival of the first business information systems (e.g. Dumas & van der Aalst & ter Hofstede 2005). Popular examples range from Petri nets (Petri 1962), event-driven process chains (Scheer 2000) and UML activity diagrams (Object Management Group 2004) to the Business Process Modeling Notation (BPMN) (Object Management Group 2006).

Languages for representing business processes try to avoid the fuzziness of natural language descriptions. The inherent impracticability of mathematical formulations should be replaced by semi-formal, graphic forms of representation (Thomas & Fellmann 2007). However, with a semi-formal specification of business process models (e.g. with the help of the event-driven process chains) an automated model analysis apart from syntactic analysis is hardly possible. Nevertheless, the automated semantic analysis of business process models would allow significant cost saving potential in contrary to manual evaluations. Current broadly distributed, commercial modeling tools provide only limited support for the automation of analyses (van der Aalst & ter Hofstede & Weske 2003).

Business process analysis is a highly relevant area in business process management research (Mayer & Benjamin & Caraway & Painter 1998). Van der Aalst & ter Hofstede & Weske (2003) see business process analysis as an “emerging area”. Formal analysis techniques can deliver important support during BPR efforts (van Hee & Reijers 2000). A precondition for the appropriate analysis of process models is not only their syntactic correctness, but also their semantic comparability. Researchers have conducted much research in overcoming automatic analysis problems especially with the help of ontology-driven approaches that propose the resolution of modeling differences ex-post (e.g. Born & Dörr & Weber 2007, Höfferer 2007). Despite this fact, research still indicates problems in conducting automatic analyses (Becker & Weiß & Winkelmann 2010b, Yu & Wright 1997).

The value of process modeling can only be uncovered when time-consuming analysis is performed at best automatically in various ways. Therefore, we propose an approach for the automatic analysis and detection of weaknesses in semantically analyzable business process models. We base our findings on the semantic business process modeling language (SBPML) for banks proposed by Becker & Weiß & Winkelmann (2009) and Becker & Weiß & Winkelmann (2010a). As the need for extensively analyzing business processes for multiple purposes is currently of major relevance in the banking sector (Becker & Weiß & Winkelmann 2010b, Drake & Hall & Simper 2009, Harmon & Wolf 2008), we especially address the needs of the banking domain. With the shared ambition among many banks to industrialize banking processes (Wilken & Maifarth & Lehmann & Ziggel & Ziganke & Borchert & Geske 2008), the need to model, document and analyze the process landscapes of banks is omnipresent and has become even more important due to the financial crisis. For process analysis, the banking sector currently uses proprietary developed software or databases (40%), self notations (35%), or observations (30%). About 20% of the banks do not invest any effort at all in process analysis or feel not capable of conducting process analysis although they would like to do it (Heckl 2007).

## 2 STATE OF THE ART IN BUSINESS PROCESS ANALYSIS

Currently business process models are mainly analyzed manually. Especially in smaller organizations, the methodical knowledge on how to collect data on business processes and how to analyze the resulting models is often not available (Benamou 2005). Therefore, external consultants are hired to construct models (Davenport & Short 1990, Rosemann 2007). These consultants, coming from outside of the organization, use their methodical skills to acquire the relevant domain knowledge. By modeling the processes they gain an understanding of the structures, products, and services of the organization. Subsequently, they manually analyze the process models with the objective of identifying potential weaknesses (Kusiak & Larson & Wang 1994) or evaluating the compliance of corporate rules and processes (Namiri & Stojanovic 2007). Furthermore, they try to identify possible risks (Herrmann & Herrmann 2006) to assess the overall performance in areas of business objects, material and organizational

resources of an organization (Kueng 2000), or to reorganize processes, e.g. through implementing ICT-concepts (Arendsen & van Engers & Schurink 2008, Becker & Bergener & Kleist & Pfeiffer & Räckers 2008). All of the above mentioned analyses can only indicate which processes may have weaknesses, but cannot pinpoint where exactly the problems within the specific processes can be located. Due to this, a common, transparent and fast way of *semantic process analysis*, a semi-automated support, is desirable.

In recent years four different approaches for the automated analysis of business process models have emerged that are uncoupled with each other (Pfeiffer 2008):

- The *formal structural approach* for analyzing business process models considers models as graphs. Similarity metrics for graphs have been suggested based on the maximum common subgraph (Bunke & Shearer 1998) or the graph edit distance (Bunke 1997).
- The *formal behavioral approach* examines the dynamic aspects of process models. The approach comprises multiple, varyingly strong equivalence notions which rely on the formal execution semantics of the underlying models (e.g. de Medeiros & van der Aalst & Weijters 2008, Hidders & Dumas & van der Aalst & ter Hofstede & Verelst 2005).
- The *semantic annotation based* approach has its roots in ontological research and is based on the foundations of conceptual modeling (Guizzardi & Pires & van Sinderen 2002, Wand & Weber 1990). It addresses the analysis of business process models by offering a common terminological reference point in the form of a domain ontology (Höfferer 2007, Thomas & Fellmann 2007).
- The *modeling language based* approach is concerned with specifically designed business process modeling grammars that enhance analyzability of models through better model comparison capabilities (Pfeiffer 2007). It addresses the problem of deviations in models by offering language constructs that limit the choices of the model creator. For this purpose, the set of constructs is carefully selected and restrictive meta models or grammars are defined.

A detailed examination of the existing approaches shows that they only partially solve semantic analysis conflicts (Pfeiffer 2008). Therefore, we argue for an integrated approach that handles all conflicts which can occur while modeling and automatically analyzing different business process models. This integrated approach is called the *semantic building block based approach*, which is an integration of the semantic annotation based and modeling language based approach (Pfeiffer 2008). The formal structural approach and formal behavioral approach are not considered for this integration as they compare models on a formal instead of a semantic level. Building upon this new modeling approach we propose to use it to discover weaknesses in business processes in the banking industry. Therefore, we will use the SBPML methodology as a first instantiation of this class of process modeling languages (Becker & Weiß & Winkelmann 2010a, Becker & Weiß & Winkelmann 2009) as a basis for the definition of process weaknesses.

Systematic evaluation of weaknesses in business process models has not been well-researched in the past, although there is an abundance of literature on business process optimization in general (mostly focusing on the different phases of process management). Many cases can be found, which demonstrate business process optimization of one or more weaknesses with regard to a certain type of business process optimization solution. This paper does not concentrate on identifying and categorizing all types of different weaknesses in business processes but rather focuses on providing a new method on how to automatically identify weaknesses in process models. Therefore we will concentrate on elaborating a few select weaknesses as commonly mentioned in the existing literature (Baacke & Becker & Bergener & Fitterer & Greiner & Stroh & Räckers & Rohner 2009).

### 3 RESEARCH METHODOLOGY

We based our research on a typical design science research approach (Hevner & March & Park & Ram 2004, Pfeiffer 2007), which begins with a problem identification. It continues with objectives of a solution regarding the state of the art. These two steps were performed in the first two sections. We identified the mainly manual analysis of process models as a problem and identified a research gap in the (semi-)automated semantic analysis of processes models. Therefore, our objective is to develop weakness patterns to allow the analysis of models based on a semantic process modeling language. In this section we give insights on the research approach used to search for the solution. As a result, our research commences with the presentation of the semantic process building block based language, which forms the basis of our approach (section 4.1). Upon that we present the development and design of the weakness patterns as an

artifact to solve the problem of defining and formalizing weaknesses. In order to demonstrate the usability of our approach we apply it in a case study at a bank. In this bank we modeled a large part of the core business processes using our semantic building block based modeling language and applied the weakness patterns to these process models. Finally, we finish our work with an evaluation of the artifact and its advantages and limitations by testing effectiveness and efficiency of the artifact in a lab experiment in section 6. Furthermore, we highlight the contribution made to the existing body of knowledge and give an outlook on possible future research (section 7).

## 4 FORMALIZING WEAKNESSES IN BANKING PROCESSES

### 4.1 The SBPML Specification for the Formal Description of Banking Processes

The SBPML modeling methodology is a domain specific process modeling approach and is based on the concept of semantic building block based languages (SBBL) (Pfeiffer 2008). It has been instantiated for the domains of public administrations (Becker & Bergener & Kleist & Pfeiffer & Räckers 2008, Becker & Pfeiffer & Räckers 2007) and banking (Becker & Weiß & Winkelmann 2010a, Becker & Weiß & Winkelmann 2009). Like other process modeling approaches (e.g. ARIS, Scheer 2000) SBPML for banks uses the concept of views to structure relevant information and thereby reduces complexity. It provides four different views to capture different aspects relevant for the documentation and analysis of business processes.

The *organizational view* captures details about the organizational context of processes. The organizational model uses the elements of organizational units, positions and staffing of positions to build a hierarchical organization plan. The elements from this view can be used in the process models to depict who is carrying out certain tasks and who is responsible for a process. The *business object view* contains details about the information, which is processed in the course of a business process. The business objects model structures different types of business objects like a credit application or a credit agreement. This allows depicting input and output of processes and enables the analysis of the information flow throughout process landscapes. The *resource view* contains information about the resources, which are utilized during a process. Resources include software and hardware but also certain skills or knowledge required for a task. The resource model structures these elements and allows for a consistent view on them. The annotation of resources used within processes enables the analysis of IT support and resource consumption in processes.

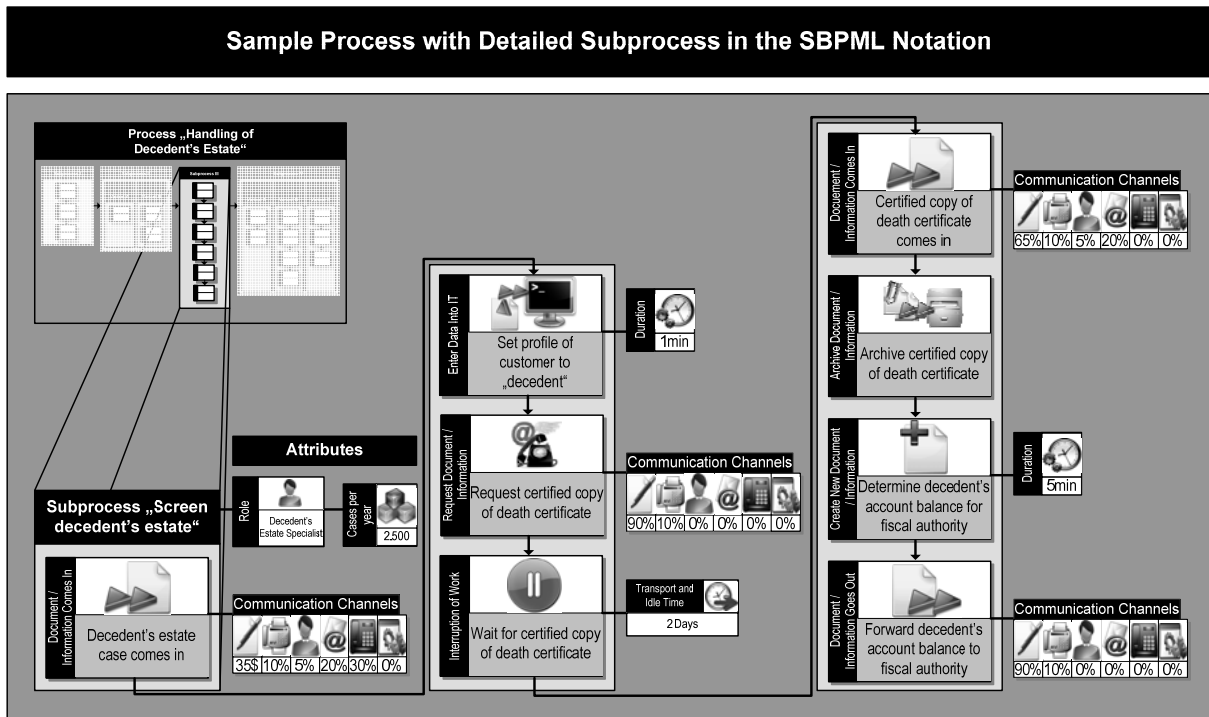


Figure 1. Sample process in SBPML notation

The *process view* describes in detail how a process is executed. It also acts as the integrating view for the other views. The process model does not only document which activities have to be performed in which sequence, but also *who* performs them (organizational view), *what* is processed by them (business object view) and *whereby* the activity is supported (resource view). Besides these elements from the other views, the process model itself consists of a number of elements for the representation of business processes. Figure 1 depicts a sample process model in the SBPML notation.

The core components of the process model are *process building blocks (PBB)*. PBBs represent the activities performed during a process. As an instantiation of class of the SBBL, SBPML defines a fixed set of domain specific PBBs. The PBBs have two specific features which allow for an automated analysis of processes. (1) The PBBs are atomic and therefore standardize the level of abstraction in SBPML process models to avoid problems like abstraction conflicts (Pfeiffer 2008). (2) The PBBs are semantically defined by domain concepts (Rupprecht & Funffinger & Knublauch & Rose 2000). Only these domain concepts result in the different types of PBBs and define their semantics. Therefore, the problem of naming conflicts cannot occur when analyzing SBPML process models.

To capture further information about how an activity is carried out, each PBB type has a specific set of attributes. These attributes specify the properties of a PBB in detail. For example, the PBB “Enter Data into IT” has an attribute “Duration” to capture how much time this activity demands. Attributes are also used to establish the connection to model elements of other views. Therefore, the PBB “Enter Data into IT” has an attribute to capture the used IT systems from the resource model. Hence, attributes provide the core information for the subsequent process analysis.

#### 4.2 Defining SBPML-based Patterns for the Description of Business Process Weaknesses

In order to generally identify different activity-based weaknesses in business processes, we have studied about 30 business process optimization projects in banks (e.g. Chase Manhattan Bank, ING DiBa, Citibank, Chinatrust Commercial Bank, Commerzbank) based on the information available on the internet (esp. on corporate portals of banks and their investor pages). Furthermore, we conducted a literature review (Harmon & Wolf 2008, Heckl 2007). We came to the conclusion that document and workflow management systems for process and document virtualization are key drivers for overcoming weaknesses in banks and for optimizing large parts of process landscapes in banks. Banks introduce them to mainly avoid media breaks, to reduce the throughput times caused by information deficits and to automate processes. With this paper we want to demonstrate the ability of our approach for semi-automatically detecting these types of weaknesses in process models and will exclusively focus our subsequent argumentation on the above mentioned weaknesses with the help of the SBPML notation.

In the following section we will define weakness patterns, which can be used for the automatic identification of potential weaknesses in process models. We will use a 2-step transformation approach to do this: we will first characterize the three weaknesses in natural language and will then try to describe the characteristics of these weaknesses using PBBs and attributes defined by the SBPML specification. We call such a description of a weakness, using the PBBs of the SBPML notation, a weakness pattern. Such a pattern consists of a PBB or a sequence of PBBs with associated attributes. It can also contain wildcards to express a number of arbitrary PBBs between two PBBs of a weakness pattern. Weakness patterns in this notation can be used to search SBPML process models for weaknesses semi-automatically. If the sequence of a weakness pattern is found in a process model this indicates a possible weakness in the process. Then, these candidate weaknesses have to be verified manually.

A media break can be defined as a change of the medium used to carry information during information processing. A typical example of a media break in a process occurs when information in the form of a paper-based document (e.g. a credit application) is received by an organizational unit and then scanned and / or information from this document is entered into an information system (e.g. applicant and credit data entered into core banking system) for further electronic processing (e.g. for credit assessment and documentation purposes). The general idea is to avoid media breaks and handle all processes electronically, since the use of IT supports nearly all core processes of banks. Assuming that a document or piece of information is processed electronically sooner or later in a process, we define the following patterns to

characterize the media break weakness: a) a document or information is received / forwarded or sent non-electronically b) a document is scanned (concluding transfer of paper-based information to digital information) or printed (concluding transformation of digital information to paper-based information) or first scanned and then again printed (assuming the same underlying business object – e.g. document or piece of information) c) data is entered into IT (as the result of transferring paper outside of the current IT system from another medium or even IT system).

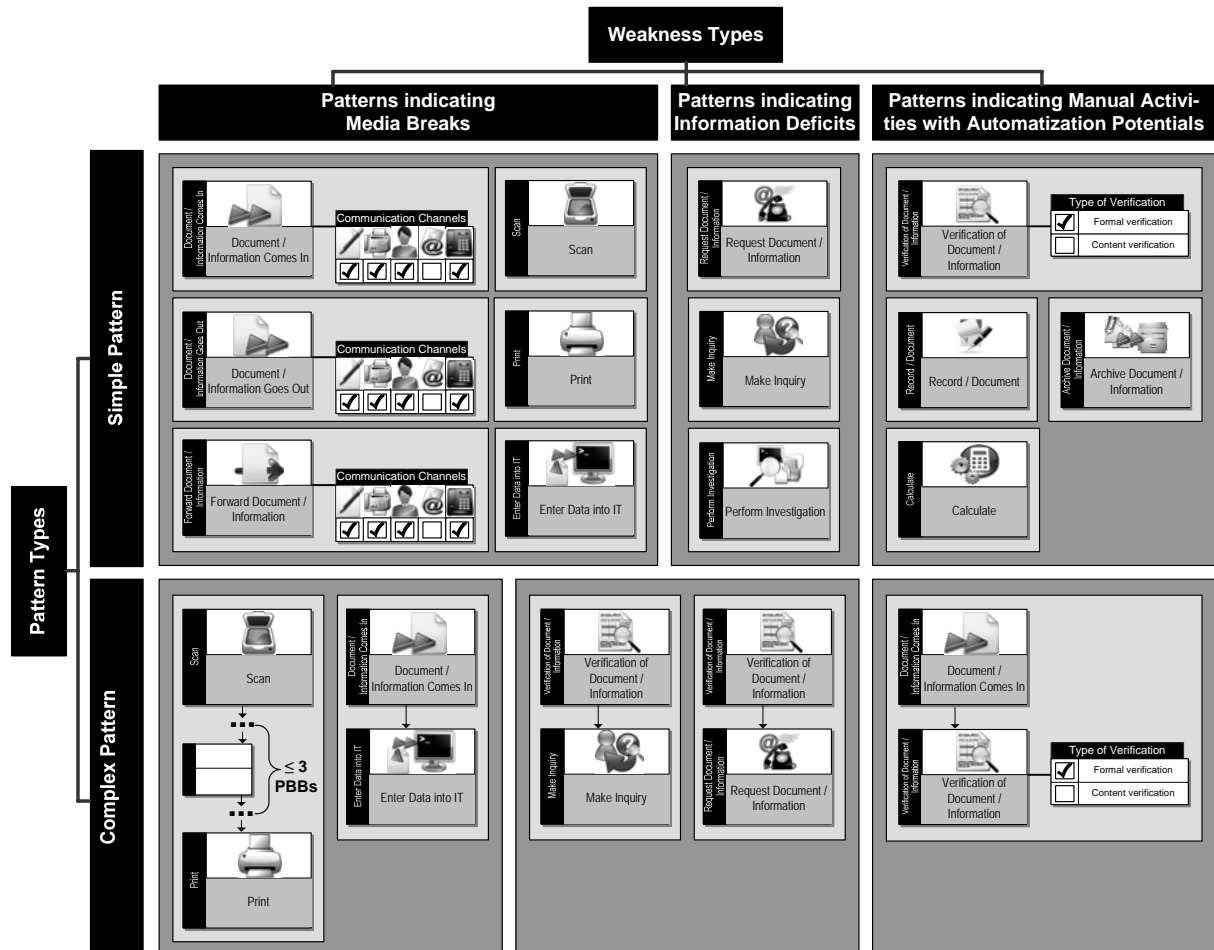


Figure 2. Examples of Weakness Patterns in SBPML Notation

An information deficit during a process execution usually prohibits a further process execution and forces further information retrieval (e.g. manual search if a company's postal address exists or an inquiry to a customer regarding a missing credit application document) with or without the help of a third party. If a third party is involved, further coordination effort is necessary. Another characteristic of an information deficit is that it can bind human resources for an unknown time frame since it may not be clear upfront where exactly the information can be retrieved and how long the information retrieval process may take. The general objective is to avoid information deficits where possible as these prohibit fast and continuous processes. Typical SBPML PBBs describing this type of weakness are: "Make Inquiry" (by telephone), "Request Document / Information" (in written form via e-mail, fax or postal mail) and "Perform Investigation" (without third party involvement). As information deficits and thus the need for further input is usually detected after existing information has been checked, we can also build more complex patterns that consist of the PBB "Verification of Document / Information" directly followed by one of the first mentioned PBBs (e.g. "Make Inquiry", "Request Document / Information" or "Perform Investigation"). However, as "Perform Investigation" can also frequently be made without a prior verification of documents or information (e.g. obtaining information from a third party agency about a customer's credit rating) due to internal or compulsory exigencies, we just focus on the first two complex patterns.



Manual activities with automation potential are usually simple routine activities that are standardized and already involve IT partly or have the potential to extend the usage of IT to completely replace the manual activity. The goal here is to reduce human labor in routine everyday processes. The previously defined media breaks can be seen as a special kind of manual activity, but – due to their importance in business process analysis – we consider them as a separate category. Based on the predefined SBPML PBBs for the banking domain, we can identify the formal PBB “Verification of Document / Information”, the act of documenting activities defined by the PBB “Record / Document” (assuming that the prior activity to be documented has also been supported by IT), “Archive Document / Information” (assuming that the document or information to be archived is digital) and “Calculate” (assuming that the necessary input data for a calculation is available digitally and can be used by an IT system for a calculation). All of these four activities with their assumptions have the potential to be automated completely. For all prior weakness types, we can define more complex patterns to reduce the possibility of falsely detecting weaknesses via pattern search even though they are not real weaknesses. For example, a typical complex pattern could include “Document / Information Comes In” directly followed by the PBB formal “Verification of Document / Information”.

In figure 2 we summarize the different SBPML-based patterns used to describe the three weakness types. In addition we differentiate between simple and hence less specialized patterns (consisting of merely one PBB and optional attribute specifications) and complex patterns (consisting of two or more PBBs directly or indirectly following each other with optionally several PBBs in between and a further option of specifying no attribute or some or all attributes for the used PBBs).

## 5 APPLYING PATTERN-BASED WEAKNESS IDENTIFICATION

To demonstrate the applicability of our formalized patterns for analyzing weaknesses in business processes, we chose to do an extensive case study at a bank, where we could model a large part of the daily operating process landscape with a focus on analyzing core banking processes. Our partner bank provided credits for over 900 banks in Germany and Austria, while at the same time also operating over 60 subsidiary shops in different cities, which only offer its credit product. In 2008 it employed over 1,000 people, which served 443,000 customers, totaling a credit volume of 4.9 billion Euros.

In this case the SBPML methodology was applied to model processes from the organizational units production, service and support center and shared services. In these units six so called end-to-end (EtE) processes, depicting the whole consumer life-cycle, were modeled and analyzed. These EtE processes consisted of 31 performance modules, which are conform to the concept of a process in the SBPML methodology. The 31 processes were captured in 35 interviews by teams of at least two modelers interviewing one or two domain experts during a two week time frame. These resulted in a total of 79 sub-processes with 242 variants and 970 PBBs. However, since it was the primary target of this phase to model all 31 processes completely to create a broad database, it was not possible to model attributes for the PBBs.

Patterns	#	Patterns	#
<b>Media Breaks</b>		<b>Information Deficits</b>	
Document/Information Comes In (*)	153	Make Inquiry	4
Document/Information Goes Out (*)	83	Request Document/Information	27
Forward Document/Information (*)	29	Perform Investigation	63
Scan	0	Verification of Document/Information → Make Inquiry	0
Print	7	Verification of Document/Information → Request Document/Information	20
Enter Data Into It	23	<b>Manual Activities</b>	
Copy	1	Verification of Document/Information (*)	157
Scan → up to 3 PBBs → Print	0	Record/Document	54
Document/Information Comes In → Enter Data Into IT	10	Archive Document/Information	11
		Calculate	7
		Document/Information Comes In → Verification of Document/Information (*)	49

Table 1. Pattern Occurrences in the Analyzed Bank Processes

In the subsequent analysis phase, we automatically analyzed this existent process landscape using the weakness patterns, which were formalized in the previous section. As the process models did not contain PBB attributes, it was not possible to search for patterns, which contained such attributes within their

definition. Instead, patterns were realized without attributes. Table 1 shows the detected number of occurrences for each pattern. Patterns, which would actually require attributes, but were searched without analyzing the possible existence of attributes, are marked with an asterisk.

## 6 EVALUATION – INSIGHTS FROM A BANKING CASE STUDY

### 6.1 Effectiveness

Developing a method, which supports the automatic identification of weakness patterns within process models, can be stated as an effective way of searching for weaknesses, if we get a result set with the correct results. Referring to Drucker (1967) effectiveness is a value for target achievement or more precisely expresses the quality of target achievement.

In our banking case study we measured effectiveness of the applied weakness patterns. For this purpose we performed two different steps. First, after defining the weakness patterns in the SBPML methodology, we analyzed all modeled processes automatically and listed the occurrences of weakness patterns per process. Second, to validate if every occurrence found was really classified correctly as a weakness within the process flow, we reduced the number of processes to three processes in order to do a countercheck between manual analysis and automatic analysis. For representative processes we calculated the number of found weakness patterns in relation to the number of PBBs in all processes and chose the processes with the highest (0.56), lowest (0.02) and median (0.3) weakness patterns per PBB.

Subsequently, we conducted a lab experiment with three master students, who had extensive training in process modeling and analysis and had already done this professionally in public administrations and banks. None of these students were involved in the development of the process patterns. These students were given a short textual description of the weakness types, as discussed in this article (but not the corresponding patterns), and were asked to find these weaknesses in the process models manually. The experts then manually identified weaknesses for these three processes in a 2-step process. (1) First, all three processes were analyzed by each student individually. (2) Then, the results were consolidated with a consensus-approach in an open discussion. During this step the three students decided via logical argumentation and finally majority vote on each potential weakness that they had found during their individual analysis phase, if it was a valid weakness or falsely identified as a weakness. It turned out that, every student was able to manually identify between 75% to 87% (average was 82%) of the weaknesses they all agreed upon. (3) After that, the same experts also compared their manual results with the automatically performed pattern search:

(1) Apart from one weakness pattern occurrence the automatic analysis listed all occurrences of weakness patterns, which were also identified manually. In this special case the students were not able to come to a consensus regarding if the manually identified weakness pattern definitely was a real weakness, based on the given information annotated in the process description. This leads to the conclusion that the characterization of the weakness patterns in SBPML was well chosen, i.e. the definition was not too restrictive.

(2) Nevertheless, the weakness pattern definitions, which were initially depending on attribute specifications, are problematic when evaluating effectiveness of the SBPML methodology, as they are not as accurate or in the worst case do not characterize the weakness types correctly. Therefore, only taking weakness patterns without attributes into account, we can state that all patterns identified with the SBPML were also identified as weaknesses by the analysis experts. Beyond that, our SBPML approach identified additional pattern occurrences, which were not categorized as real weaknesses by the analysis experts afterwards. These weakness occurrences were related to manual documentation activities due to regulatory compliance, which were thus not identified in the manual analysis step by the experts.

(3) Reflecting on the weakness patterns, which needed attribute values for a reliable automatic detection and classification as weaknesses, we got involved in a discussion with the students. Based on the given information there were hints that the listed occurrences were actual weaknesses according to the PBB descriptions. Finally, the experts agreed that without further information in the process models, it cannot be terminally decided if the SBPML approach found weaknesses or listed useless results. For example, we

may not be in the situation to change process flows since for example media breaks or signatures may be mandatory due to state regulations.

Finally, the fraction of the number of real weaknesses divided by the number of not optimizable weaknesses defines the effectiveness of finding an actual weakness. Logical argument, based on our given argumentation in 1), results in nearly 100% effectiveness of at least finding the pattern (no matter if it is a real weakness or not).

## 6.2 Efficiency

According to Drucker (1967) efficiency means doing something, which can already be achieved, in a better or optimized way. In our case study we measured the efficiency of the applied approach for identifying weaknesses by comparing the relation of identified weaknesses – which meant workload for us – with the time needed for manual and automated search for weakness patterns. The automated SBPML analysis is more efficient than manual business process analyses approaches if the value of the workload – time needed – relation of SBPML usage is higher than the workload – time needed – relation of manual analysis. We monitored the evaluation of our artifact as described above and found that manual evaluation of the chosen processes, including time for finding a consensus among the students, accounted for 69 minutes of workload on average for each student.

In contrary, automatic retrieval of weakness pattern occurrences with the SBPML method, implemented in the SBPML software tool, took less than one minute using a typical desktop computer. However, the students still had to manually check all automatically identified patterns in order to be sure that they really were weaknesses. This proof of plausibility took 17 minutes for each student. Hence, time spent on automatic analysis with a subsequent manual proof accounted for 17 minutes per student or one fourth of the manual analysis. Thus, the SBPML approach can be stated to be more efficient than manual process analysis.

For our efficiency comparison we did not add the nonrecurring efforts for defining the weakness patterns within the SBPML methodology, as we see this as initial costs, which only arise one single time. After the initial definition, the defined weakness patterns can be reused in other projects without additional effort since these patterns are then already known and existent in our software tool. However, as students first had to manually identify weaknesses and then had to countercheck the automatically identified patterns, critics may argue that there is a learning curve that leads to shorter review times in the second place. We agree with it. However, the performance gain of being four times faster during analysis is apparent, even having this effect in mind. As a consequence, we will evaluate the process model a) with a larger group of modeling experts and b) with separated groups for the manual analysis and for counterchecking the automatic analysis.

## 6.3 Limitations

Reflecting the approach of pattern-based business process analysis, at least two main limitations should be discussed for further research:

*The pattern-based approach depends upon how well weaknesses are defined and formalized.* They remain “potential” weaknesses until a manual analysis reveals that the identified potential weaknesses are actually real weaknesses or not weaknesses, e.g. due to law regulations. Although the approach can be refined iteratively through empirical evaluation, this depends on the given input for the algorithm. We do not want to discuss the potentials of the area of artificial intelligence and the possibility of automatically learning from the pattern-based approach in this context, but leave this limitation as is for further examination. Generally speaking it is best to characterize weaknesses with as much detail as possible and also to formalize as many of these characteristics as possible to find better pattern matches, which result in not just potential but real weaknesses being found. Following our actual set of weakness patterns this also means defining more complex weakness patterns in a next evaluation step compared to using simple patterns to increase effectiveness of our approach. This will help us to find more complex and also more hidden potential automatically through defining process-spanning weakness patterns in combination with more complex attribute combinations.

*The identification of the patterns also depends upon how well the processes have been documented. If processes have been documented without many attributes or even without using the organizational view and/or resource view and/or business objects view, then only very simple patterns may be possible for automated analysis, as only these have a chance of being found in the process landscape. So maybe the efforts necessary in the phase of process modeling will be rising compared to the possibilities of manual weakness pattern search done by an experienced consultant, who does not need as detailed information due to his knowledge.*

## 7 CONCLUSION

With respect to our contribution to the body of knowledge, we have conducted design science research according to the design research guidelines, defined by Hevner & March & Park & Ram. (2004), by creating an innovative and purposeful artifact for a pattern-based automated analysis of semantic business process models in the banking sector. By developing, applying and evaluating our approach, we have provided a research artifact in a rigorous design science research cycle. Applying our approach in practice, it turned out that our modeling and especially our automated analysis approach is highly relevant to the domain of banking and offers much potential for the identification of weaknesses and hence for improvements in banking processes. In sum, the approach allows a flexible, fast and automatic evaluation of semantic process models based on predefined weakness patterns not only by modeling experts, but also by decision makers.

To generalize our findings, we propose a 4-step business process analysis methodology for applying our pattern-based weakness analysis approach to different weakness types and even other domains:

- **Identification & Characterization:** Explicate weaknesses within a given problem domain with regard to possible optimizations.
- **Formalization:** Formalize the characterized weaknesses with as much detail as possible with the help of semantic patterns using a specific semantic business process modeling language syntax.
- **Application:** Apply the patterns to process models (which include all necessary details also used to characterize weaknesses) using the same SBBL syntax to identify possible weaknesses.
- **Validation:** Manually validate every possible weakness (identified automatically in the previous step) to specify if and how an optimization may be possible.

It was possible to use the advances in business process modeling languages to enhance traditional approaches to business process analysis and extend these to in-depth process and activity-based analysis. However, as we argued in our limitations, our methodology for business process analysis is only as good as the people who use it and depends upon the careful definition of weaknesses and collection of relevant information, to avoid too many detected weaknesses without too many actual weaknesses and to also avoid too few findings, missing all similar or related weaknesses to be found as well. In addition, we think that our approach can be applied to process models in different industries, given that they use semantic business process modeling languages.

Therefore, we suggest future research in the area of how to define the weakness patterns with as much detail as possible. In addition, we recommend research on creating a detailed taxonomy of the different types of weaknesses to be found in business processes of banks and even in general in different industries. Finally, we recommend research on applying our enhanced business process analysis methodology in the context of more cases and even different industries to prove the generality we assume in our approach. Giving an outlook on what more potential the idea of semi-automatically identifying weaknesses in processes has, we can also imagine that it can be possible to semi-automatically suggest optimization patterns for optimizing identified weaknesses.

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