# Automatic Identification of Structural Process Weaknesses – Experiences with Semantic Business Process Modeling in the Financial Sector

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## ABSTRACT

Business process reengineering (BPR) has been a core research topic for at least the last twenty years. As banks have realized the need to look on their business in a process-oriented way, they have been engaged in numerous business process reengineering projects 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. Based on the Semantic Business Process Modeling Language (SBPML) this paper introduces a new approach for pattern-based automatic process model analysis, with a focus on identifying structural process weaknesses such as organizational process fragmentation, possibly unnecessary process complexity or multiple resource usage or other process inefficiencies. Additionally, this approach also allows for a benchmarking of different process path alternatives in the same process or among different processes. In this article, this approach is applied and evaluated in the financial sector, but it can possibly also be used in other domains. It contributes to a more efficient and more effective identification of possible weaknesses in process models in comparison to today's manual analysis of process models.

## Keywords

Business Process Management, Business Process Analysis, Business Process Modeling, Banks

## 1. INTRODUCTION

Process models have been established as a broadly applied instrument in business process management. Therefore,

researchers have developed many modeling languages for the formal representation of business processes since the arrival of the first business information systems [24, 61]. Popular examples range from Petri nets [47] over event-driven process chains [39, 53] and the UML activity diagram [46] to the Business Process Modeling Notation (BPMN) [45]. With the help of these modeling languages it is possible to construct a formal representation of real world processes. These models allow a documentation and communication of as-is business processes as well as to-be definitions of future business processes in software development and business process reorganization projects [30]. They describe the logical sequence of activities, the resulting products and services, the required resources and data, as well as the involved organizational units [42]. These process models can be used e.g. as a basis for decisions on IT investments, reorganizations or the selection and implementation of information systems.

Languages for representing business processes try to avoid the fuzziness of natural language descriptions by more formal process representations. However, the inherent impracticability of mathematical formulations is represented in semi-formal, graphic forms of representation [54]. Fundamental work has been done in the field of graph theory [26]. Based on a given graph, these approaches discuss the identification of structurally equivalent (homomorphism) or synonymous (isomorphism) parts of the given graph in other graphs. However, with a semi-formal specification of business process models (e.g. with the help of event-driven process chains or BPMN process models) an automated model analysis of model elements and models is very difficult in terms of semantic similarity. However, it may be possible to identify patterns in process models on a syntactical level in order to analyze the occurrence of a particular collection of model elements (e.g. the number of different IT systems used as an indicator of media breaks in a process) [50]. Such an automated analysis of business process models could allow a significant cost saving potential in contrast to manual analysis of process models. Nevertheless, today's popular commercial modeling tools provide only a very limited support for the automation of these types of analyses [13, 55]. As a result, researchers come to the conclusion that e. g. banks do not fully

exploit the potential of process analysis compared to the conducted effort they put into process modeling [10].

Business process analysis is a highly relevant area in business process management research [43]. Van der Aalst et al. see business process analysis as an "emerging area" [55] as research still indicates problems in conducting automatic analyses [60]. Formal analysis techniques can deliver important support during BPR efforts [56], but also for benchmarking. Due to the size of process models and their complexity, companies strive for a solution that allows an automatic business process analysis [19]. The value of process modeling can only be uncovered when time-consuming analysis, regarding the discovery of process weaknesses, is performed. According to Drew [23] „a process weakness […] should be seen as an opportunity to improve a process or to exploit a change for the better." Therefore, a new approach for automatic analysis and detection of potential process weaknesses (e.g. indicating possible process improvement potentials) in structurally analyzable business process models is suggested in this article.

In systems analysis and design, so-called design patterns are used to describe best-practice solutions for common recurring problems. Common design situations are identified, which can be modeled in various ways. The most desirable solution is identified as a pattern and recommended for further usage. The general idea originates from [1], who argued about patterns in the field of architecture. In IS, patterns are commonly used in system design or workflow modeling. However, in most cases, patterns are not used for matching but for the manual implementation of best practices (for a detailed discussion cf. [8]). Hence, the underlying research question of this article is:

***How should business process patterns be defined that allow for an automatic identification of structural process weaknesses and for process path benchmarking?***

In order to achieve this research aim, a comprehensive case analysis was conducted. As the need for extensively analyzing business processes for multiple purposes is currently of major relevance in the banking sector [31, 22], a case from the banking industry was chosen, in order to evaluate the newly defined structural process weakness patterns. The findings are based on the Semantic Business Process Modeling Language (SBPML) as this process modeling language has been specifically developed to the needs of the financial industry with regard to process modeling and analysis [9]. However, the findings presented here are neither limited to the modeling language nor to the financial sector.

This paper is structured as follows: section 2 introduces the theoretical foundation of the approach. Subsequently, the applied research methodology is discussed along with the issues of method selection, case selection, and data collection and analysis. Following the development and demonstration discussion in section 4 and 5, the implications for theory are reflected and new vistas are suggested for BPM practice in terms of process improvement and benchmarking. The final section contains conclusions.

## 2. THEORETICAL FOUNDATION

Currently business process models are mainly analyzed manually [57]. Especially in smaller organizations, the methodical knowledge of how to collect data about the business processes and how to benchmark process models is often not available [11]. Therefore, external consultants are hired to construct and evaluate models [17, 52]. 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 [4, 5, 41] or evaluating the compliance of corporate rules and processes [44]. Furthermore, they try to identify possible risks [33, 38], to assess the overall performance in areas of business objects, material and organizational resources of an organization [41, 7], or reorganize processes, e.g. through implementing ICT-concepts [2, 6].

In recent years four different approaches for the automated analysis of business process models have emerged that are uncoupled with each other [50]:

- *The formal structural approach* for analyzing business process models considers models as graphs. Similarity metrics for graphs have been suggested based on the maximal common sub graph [16] or the graph edit distance [15]. Recent research suggests to apply formal patterns to compare and analyze the formal structure of process models [20; 59]. In the structural approach two business process models are equivalent when they have the same formal structure.

- *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. [3, 18, 35, 36, 51]). In general, two business process models are considered equivalent in this approach when both models show an identical behavior during a simulation.

- *The semantic annotation-based approach* has its roots in ontological research and is based on the foundations of conceptual modeling [29, 58]. It addresses the analysis of business process models by offering a common terminological reference point in the form of a domain ontology [27, 37, 54]. Two model elements are identical when they refer to the same ontology element.

- *The modeling language-based approach* is concerned with specifically designed business process modeling grammars that avoid semantic conflicts in the first place [49]. It addresses the problem of deviations by offering language constructs that limit the choices of the model creator. For this purpose, the set of constructs is carefully selected, and restrictive metamodels or grammars are defined. In this approach, two model elements are the same when they have been constructed from the same real world fact.

In this paper, the formal structural approach is addressed since structural patterns for an identification of process weaknesses and hence a comparison and benchmarking of processes and

process path alternatives are proposed for SBPML in line with [59] who propose patterns for flow chart diagrams.

# 3. RESEARCH DESIGN
## 3.1 Research Propositions
Automatic business process analysis is seen as a relevant research topic [43, 55]. This research aims at contributing to the general body of knowledge on process analysis and at introducing a holistic approach for pattern-based analysis of structural weaknesses in processes. Hence, with the presented formal structural approach the automatic identification of structural weaknesses in business process models is addressed in order to make business process analysis within BPR projects and therefore benchmarking projects more efficient and effective. For doing so, three propositions, which will be addressed throughout this paper, are set up.

### Proposition 1 – Identifiability of Weaknesses

Recent studies on processes in banking report about media breaks, missing information, competency frictions, etc. [4, 28, 29, 32]. Hence, despite of reorganizations during the last centuries, there are still many weaknesses in business processes from banks. Thus a first proposition (P1) may be stated as that it is possible to identify most of the structural process weaknesses automatically, as long as these can be clearly characterized. Characterizing weaknesses is then the basis for defining weakness types and transferring these weakness types and their characteristics later on (cf. P2) into formalized patterns. The automatic identification and analysis will mean cost reductions due to time and resource savings in the process of analyzing business processes.

### Proposition 2 – Formalizability of Weaknesses

As a second proposition (P2) it may be proposed that weaknesses can be generalized, with regard to defining different "weakness types", and thus can be described and formalized with the help of "structural patterns". Those patterns consist of different elements that describe the characteristics of the given weaknesses and can be used for any process.

### Proposition 3 – Effectiveness of the Automatic Identification of Formalized Weaknesses

The possibility of identifying and formalizing structural weakness patterns (P1 and P2) are a necessary prerequisite for an automated identification of structural weaknesses in SBPML. In a final step, the last proposition (P3) shall state that the approach is capable of automatically identifying, correctly classifying and analyzing typical weaknesses in business processes on a syntactic level.

## 3.2 Research Framework and Methodology for Automatic Identification of Structural Process Weaknesses
To prove that the guiding propositions above hold true and thus it is possible to improve business process analysis and benchmarking, we follow a typical design science research approach [34, 47], which begins with a problem identification (as done in section 1). It continues with objectives of a solution regarding the state of the art (as done in section 2) and gives insights on the research approach used to search for the solution (this current section 3). As a result, this research commences with the development and design of structural weakness patterns for SBPML as an artifact to solve the problem of defining and formalizing weaknesses, and applying these to process models (section 4). In order to demonstrate the usability of the approach, it is applied in a given context (section 5). Finally, the work is supplemented by an evaluation of the artifact and its advantages and limitations (section 6). Finally, a critical recapitulation of the overall research is done, with respect to the research propositions, the contribution made to the existing body of knowledge and an outlook on possible future research (section 7).

# 4. ARTIFACT DEVELOPMENT

## 4.1 Activity-Based Analysis of Structural Business 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 business process management). Here, 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 and also does not do this limited to the given domain of banking. The goal of this paper is to find and show a method that is able to identify structural weaknesses in process models automatically.

Van Heen and Reijers differentiate analyses for BPR into qualitative and quantitative analyses [56] of which especially the latter are addressed. While qualitative analyses focus on the question whether a process design meets a specific property (e.g. a bank employee should not be able to also authorize a cash transfer that he has initiated himself), quantitative analyses focus on simulation techniques (allowing for example approximations on how long a customer has to wait in a call center) and analytical techniques (allowing the calculation of the shortest path leading to a successful credit offering). For example, in the context of BPR projects, Desel and Erwin concentrate on performance analyses of business processes (calculating important key indicators such as throughput time) to identify weaknesses [19]. However, performance analyses for identifying possible weaknesses have also had a long tradition of research with previously developed and common approaches like activity-based costing [14].

According to Biazzo, the following four business process analysis approaches for quantitative analyses can be defined [12]: process mapping, coordination analysis, action analysis and social grammar analysis. *Process mapping* refers to process capturing and modeling. It concentrates on constructing the hierarchical-logical structure of processes and then using the identified activities to break these down. As this is not focused on weaknesses, but on the general reconstruction of business processes, process mapping is not discussed further.

*Coordination analysis* supports the analysis of what kind of information actors receive, from whom they receive it, how they receive it, how they process it and to whom they send outputs as a result. From a weakness analysis point of view, coordination analysis can be performed at least partially automatically with the help of many traditional process modeling languages since these languages typically have own constructs for modeling and separating organizational views from a process view and a business objects view. Therefore, this type of weakness analysis will also not be pursued further. *Action analysis* refers to the identification of activities within a given process and an in-depth exploration of the structural conditions, within which the individual activities take place. Complementing action analysis, *social grammar analysis*, according to Biazzo, pursues the analysis of a network of activities and the actitivities' possible sequence order and puts a focus on identifying the lexicon regarding the activities under study [12]. Action analysis and social grammar analysis, focusing on the analysis of activities inside of different business processes, is however a current problem. Previous modeling languages do not make many restrictions regarding the depth and breadth of activities that should be modeled or the naming conventions and the used terms that should be included in business process modeling. Therefore, this article focuses on the automatic analysis of activity-based weaknesses as this remains a known problem with challenges regarding the semantic interpretation of activities.

To analyze weaknesses, different generic activity-based weaknesses in business processes need to be identified upfront. This was done on the basis of studying about 30 business process optimization projects in banks (e.g. Chase Manhattan Bank, ING DiBa, Citibank, Chinatrust Commercial Bank, Commerzbank) and a literature review [4, 28, 31, 32], in which information was gathered from online resources available on the internet (esp. on corporate portals of banks and their investor pages). This led to the conclusion that the introduction of document and workflow management systems, to handle day-to-day business largely electronically to avoid media breaks, the reduction of throughput times and the transformation towards lean processes, as well as industrialization were key drivers for overcoming weaknesses in banks and optimizing large parts of process landscapes in banks.

As not all general weaknesses identified in this project review can be analyzed in depth, using a reasonable amount of research capacity (human resources and time), and since the aim in this article is to demonstrate the general ability of the presented approach for automatically detecting structural weaknesses in process models and locating them, a focus will be kept on a few major types of specific weaknesses, with regard to the weaknesses mentioned above. These will then be used in the further research activities in section 4.2 (artifact development) and section 5 (artifact demonstration). Examples of common weakness types, to be pursued in this paper, are: high process complexity / low standardized processes, possibly redundant activities (such as loops), process fragmentation and organizational breaks.

## 4.2 Formalizing Structural Weakness Patterns in SBPML

The Semantic Business Process Modeling Language (SBPML) is a business domain specific language [9]. Similarly to many other languages such as EPC, it consists of a process view (how is a service delivered?), a business object view (what is processed/produced?), an organizational view (who is involved in the process?) and a resource view (what resources are consumed?). The main constructs of the modeling language are domain-specific process building blocks (PBB). They represent a certain set of activities within an administrative process and apply the vocabulary of the domain. Process building blocks are atomic, have a well-defined level of abstraction and are semantically specified by a domain concept. Examples for process building blocks are "Incoming Document", "Formal Verification of a Document", or "Archive Document", which are further defined by attributes such as "input channel" or "duration". With the help of building blocks, a sequential order of activities, within an administrative process, can be specified that describes the actual sequence of activities performed during one instance of a workflow.

The predefinition of patterns, attributes, and the sequential order restrict the degrees of freedom of the modeler and simultaneously promote the construction of structurally comparable models. As many processes are quite complex and run through several different organizational units, it is possible to define sub-processes that are conducted by just one employee. However, the strict sequence does not allow for intersections. As a solution, SBPML allows either the modeling of process variants that define an alternative sequence within a sub-process or the annotation of attributes that can be used to specify different cases with percentage values. Furthermore, an anchor allows for establishing connections between process building blocks in different sub-processes and variants to enable parallel process structures. For a further introduction to the modeling concept see [9]. A detailed insight is not necessary for this article as the language only serves as an example for structural weakness analysis using a BPM language.

To systematically derive process weaknesses that can be formalized, each language element of SBPML was analyzed, according to its application in a business process modeling project in a bank. The elements used were the following:

- (core) processes: which represent end-to-end processes from the beginning of a customer or business department request until this request has been fully dealt with (e.g. responded to or taken note of)
- support processes: which are similar to core processes or a sub processes, but have the characteristic that they are "used" by multiple other core processes that usually send information to these support process and can also require a feedback from these support processes before continuing with their sequence of activities
- sub process bundles: referring to groups of sub processes of the same core process and that would represent relatively autarkic economic services and could be offered as stand-alone services to other businesses

- sub processes: which provide different levels of abstraction within the process models, as well as reduce the level of complexity and thus increase process model comprehension
- sub process variants: that describe the different, but very similar alternative activities that a sub process can have, due to a prior decision that was made in the previous process path
- process building blocks (PBB): representing the actual activities that employees perform
- control flows: to describe the sequence in which the activities (PBB) are performed
- organizational units: which are responsible for certain sub processes and that can be characterized by job position types (e.g. credit specialist) and the corresponding employees
- external partners: that can either be customers, business companies or governmental institutions and can also execute certain sub processes, for which the bank can have a responsibility
- activity operators: that define organizational units, job position types and employees, or customers that execute activities (PBB) in a specific sub process and are different from the organizational unit that is predefined as the "standard executing" organizational unit for a sub process
- resource types: defining different categories of resources (e.g. IT hardware vs. IT software)
- resources: representing the actual resources used in an activity (PBB)
- business objects: referring to information, documents or material objects that are processed within each activity (PBB)

All of these elements were analyzed together with experts from a bank, a business consultancy and several BPM researchers to systematically derive possible process weaknesses that the elements could indicate. Just by focusing on single elements it was already possible to describe situations, in which certain elements would indicate a process weakness or optimization potential. For example, many departments, participating in one process, may be an indicator for process inefficiencies. In addition, by focusing on multiple elements that could be connected to each other within a process model, it was possible to define further approaches to systematizing process weaknesses. For example, many process activities (PBB) supported by different resources may indicate a high and non-standardized resource consumption. Thus, it was possible to formalize process weaknesses on the basis of the elements that the SBPML notation offered and it was also possible to derive quantitative key indicators for possible process weaknesses from the structural patterns. For example, a key indicator was defined for evaluating if a certain process path was good or not by automatically counting the number of activities along the different sub processes that a certain process path had. In addition, the number of organizational breaks, which a process or even a certain path within the process had, could be defined by counting the number of different organizational units involved in a process. This basic approach allows for benchmarking the same processes done differently in different banks or even only branches with the help of quantitative key indicators for process weaknesses. In addition, it was recognized that by only analyzing

possible paths, which a process instance could take throughout a process model, a "benchmark" path could be defined that would depict the best possible path for the bank with minimal process weaknesses as opposed to other alternative process paths. For example, other process path alternatives would have more decisions, more tasks and maybe even an undesirable end event for example. To demonstrate the potentials of the developed approach, a close cooperation was conducted with BPM experts from a well-known German bank, as described in the following.

# 5. ARTIFACT DEMONSTRATION

## 5.1 Background Information on Underlying Banking Case

To demonstrate the applicability of the formalized patterns for analyzing weaknesses in business processes, an extensive case study was done together with a bank. A banking partner was sought, whose daily business would be the most frequently studied banking business processes in the literature, i.e. the credit process, as this would also generally be similar and thus relevant to many other banks. The selected bank partner for the demonstration case was a bank, which operated only a single product – namely consumer credits. The 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 offered its credit product. It employed more than 1,000 people in 2008, who together as a bank served 443,000 customers, totaling a credit volume of 4.9 billion Euros.

The bank followed the paradigm of continuous process improvement throughout the entire process landscape and thus had its own professional business process management team, which was responsible for the entire process management cycle (process strategy, process design, process implementation and execution and process monitoring). It had recently shifted the focus of its process modeling effort from highly detailed and fragmented process models to complete and less granular, but end-to-end process models. Therefore, the credit application process was analyzed from an end-to-end perspective (meaning the entire process once the credit application would be turned in to the bank by a customer via postal mail until the bank would have finally rejected the credit application or made a credit offer and thus successfully closed the initial credit application case for a customer) regarding possible structural process weaknesses. For the demonstration, the details of the process model will be briefly described in the following.

## 5.2 Exemplary Process Model

The process model, which was chosen for the demonstration case, depicted the "credit application via postal mail" process. It included the complete activities starting from when a credit application (originally received via postal mail) entered the bank's production department, went through several credit scoring phases until a final decision was yielded and returned to the credit applicant. The details of the process model will be briefly described as follows.

Typically, the credit order arrives by postal service, is then scanned by an external service company and then available in the document management system of the bank. It arrives in the

production department once the contractor sends an electronic message to the bank's workflow management system, triggering the further production process, to start the credit process. At first, bank employees will have to search for the customer in their database. It may either be that they will identify the customer as an existing customer and will have his documents at hand or not or that they will have to register the new customer first. In addition, a second credit applicant may have applied together with the first credit applicant (i.e. married couple) so that the production department employee will also have to collect this data. After data completion the customer's data needs to be approved in order to decide for an initial credit approval step. The approval can be done by also taking data from an external credit rating agency regarding the creditworthiness of the client or without this check if the client has disapproved this check beforehand. If the first approval check is positive (green) or semi-positive (gray) the bank will check further documents such as the income statement or further obligations. It does this in a second step to avoid unnecessary work since a good share of the credit applicants already fails this first simple credit approval step. In any other case (red decision), the credit order will be rejected immediately and archived. Once the first approval step has been successful (green) or semi-successful (gray) the second credit decision will be done.

The second credit decision will again lead to a positive (green), semi-positive (gray) and negative (red) decisions. It is also possible that a second decision will be postponed due to missing documents. In that case additional documents need to be supplied before a final decision can be made. Again, a negative decision will lead to a credit order rejection. A positive decision will lead to the creation of a credit offer. The credit process can be gray due to contentual or technical problems. Contentual problems can be any problems due to inconsistencies in the data the customer has supplied and need to be settled directly with the client and possibly also the credit rating agency. Errors will be corrected and a final credit decision will be initiated again that can again result in a green, grey or red decision. Technical problems can be for example if there is a problem with the IT system so that the second approval has to be performed again. Once all problems are solved and the client is rated to be creditworthy a credit offer will be released. If, however, the second credit approval phase results in a red decision an additional fraud check is made. If the fraud check turns out to be positive both the legal department and even the police are contacted immediately, before the credit is rejected. If a credit fraud could not be detected the credit applicant will only be rejected.

After several expert interviews with employees from the production department, which were executing and also managing this process in the bank, the final process model was derived together with two experts from the BPM department of the bank.

## 5.3 Application of Structural Patterns for Automatic Identification of Structural Weaknesses

To apply and evaluate the approach of automatically identifying structural process weaknesses, we developed a prototypical implementation on the basis of an existing meta modeling tool

from a previous research project [21]. This meta modeling tool was capable of defining non-domain-specific general process modeling languages and was adjusted to also be capable of defining the domain-specific SBPML process modeling language. We then defined the SBPML language using this meta modeling tool and were then also able to model our sample credit application process, using our predefined SBPML notation.

For analysis purpose, the meta modeling tool also already had a built-in analysis component in terms of a plugin that could be used to define patterns related to a predefined process modeling language [21]. For example the existence of certain elements like an organizational unit and an activity in a process graph could be formally defined as a pattern and it was possible to match the patterns on the basis of a given process model. Thus, we used the pattern definition scheme of this analysis component to formally define the process weakness indicators, depicted in Table 1. Along with the pattern definition functionality we used the pattern matching functionality of the analysis component [21] to count the occurrences of process weakness patterns in our given process model.

We discovered that it was possible to automatically detect various process fragments that had the possibility for a process improvement, by using our predefined process weakness patterns. For example, several cases, where several different resources (e.g. IT applications) were used in parallel, were detected that were not yet synchronized regarding data exchange. In addition, many quantitative key indicators for benchmarking the process with other banks or just benchmarking certain paths with each other within this one process were detected. The most challenging, but also most interesting benchmarking and weakness analyses were the result of a combination of several analysis possibilities including path analysis. For example, it is possible to detect the "optimal" process path that includes the least number of decisions, the least number of activities and leads to a desirable outcome for the bank.

In Table 1, the quantitative key indicator values are presented for the process under evaluation, along with triggers to indicate, which value may be interpreted as a (possible) weakness or not. More key indicators to benchmark or evaluate business process models can be developed by combining these simple indicators with each other to form relative instead of absolute quantitative key indicators. In addition, more quantitative key indicators can be derived on a "per path" and even "path type" (desirable path, optimal path etc.) basis, when different paths are to be compared automatically to detect possibly unnecessary activities or activities, which should be avoided. For the analysis of the credit application process model, all information that was available from the existing process model was used to calculate the different values.

These identified potential process weaknesses were then discussed with officials from the production department and BPM department of the bank as well with a major German consultancy, which was specialized in analyzing and optimizing business processes in banks. Most of these potential weaknesses could be verified to be actual process weaknesses. However, the triggers were suggested to be set to less extreme values for the identification of potential process weaknesses in future process analysis endeavors. In addition, the bank suggested to

concentrate on selected indicators and not analyze all indicators at the same time, depending upon the type of optimization project to be accomplished (e.g. reorganization of processes with regard to the people involved in certain processes versus the reduction and integration of IT systems, databases and other resources). This was due to the fact that the bank planned on using this automatic discovery approach in the future not just for analyzing a single process model, but for analyzing a larger set of multiple business processes or even the entire process landscape at the same time. By defining more liberal triggers and selectively applying the analysis indicators, the bank wanted to discover only the most promising processes for potential process optimization projects. Especially, it was realized that it would often not be possible to improve on all indicators for a certain process at the same time, but usually a tradeoff would be necessary for improving a process with regard to one or several indicators, while staying the same or even getting (a little) less good results on the remaining indicators after a completed process optimization project.

# 6. ARTIFACT EVALUATION – DISCUSSION OF FINDINGS AND LIMITATIONS

The example provides evidence, that it is possible to automatically identify structural process weaknesses and compare process paths in terms of benchmarking. Within this research project with external partners from consulting and banking, various structural weakness patterns were identified based on SBPML element occurrences and it was possible to establish a holistic approach for a pattern-based analysis of processes. As such, it was possible to automatically identify process weaknesses (proposition P1). It was also possible to define different weakness types with a different complexity and structural depth (proposition P2). The article provides general evidence that it is possible to define such structural weakness patterns and will offer a list of patterns. However, it was not possible to define an exhaustive list of structural patterns in this article, as there will always be new analysis contexts. Furthermore, it seems to be possible to transfer the introduced concept of structural process weakness patterns to other modeling languages that may offer additional possibilities for weakness patterns and quantitative key indicators.

**Table 1: Excerpt of Key Indicators for Structural Process Weaknesses in Credit Application Process**

| Involved SBPML Language Element | Quantitative Key Indicator for Process Weakness | Reason for Indicator | Trigger | Value in Process | Potential Weakness |
|---|---|---|---|---|---|
| (Core) Process | Number of core processes per business unit | Indicate high complexity of possibly non-standardized multitude of services offered | >1 | 1 | No |
| Support Process | Number of support processes per business unit | | >1 | 0 | No |
| Sub Process Bundle | Number of sub process bundles per process | | >1 | 1 | No |
| Sub Process | Number of sub processes per process | Indicates complex and lengthy processes | >1 | 9 | Yes |
| Sub Process Variant | Number of sub process variants per sub process | Indicate many paths (maybe non-standardized and including many exception handling paths that should be avoided) | >1 | 1 (5x); 2 (3x); 3 (1x) | No; Yes; Yes |
| | Average number of sub process variants per sub process in a process | | >1 | 1,555 | Yes |
| Process Building Block | Number of PBB per sub process variant | Indicate lengthy processes | >1 | 1 – 6 | No – Yes |
| | Average number of PBB per sub process variant in a sub process | | >1 | >1 | No – Yes |
| | Number of PBB per path in a process | | >2 | >2 | Yes |
| | Average number of PBB per path in a process | | >2 | >2 | Yes |
| Control Flow | Number of paths per process | Indicates many possible path variants, which may be costly as they may not lead to desirable end event | >1 | >1 | Yes |
| | Number of loops per process | Indicates that tasks are done again and again and in the worst case never ending, which is very costly | >0 | 0 | No |
| | Number of paths leading to desirable process end | Indicates that there are paths, which may not be as efficient or cost-saving as other paths to achieve a desired end event | ≠1 | >1 | Yes |
| | Number of paths leading to undesirable process end | Indicates that there are many variants, which produce costs, but nevertheless lead to an undesired end event | >0 | >0 | Yes |
| Organizational Unit | Number of organizational units participating in a process path | Indicates competency and know-how sharing, process fragmentation and lengthy processes | >1 | 1 – 2 | No – Yes |
| | Average number of organizational units participating per process path in a process | | >1 | >1 | Yes |
| | Number of switches between organizational units in a process path | | >0 | 0 – 2 | No – Yes |
| | Average number of switches between organizational units per process path in a process | | >0 | >0 | Yes |
| | Number of multiple switches between two organizational units in either direction per process path | | >0 | 0 – 2 | No – Yes |
| | Average number of multiple switches between two organizational units in either direction per process path in a process | | >0 | >0 | Yes |
| External Partner | [similar to organizational unit key indicators] | | | | |
| Activity Operator | [similar to organizational unit key indicators] | | | | |
| Resource Type | Number of resource types used in a PBB | Indicate possibly high resource consumption and maybe even resource waste | >0 | >0 | Yes |
| | Average number of resource types used per PBB | | >0 | >0 | Yes |
| | Number of resource types used in a sub process variant | | >0 | >0 | Yes |
| | Average number of resource types used per sub process variant in a sub process | | >0 | >0 | Yes |
| | Number of resource types used per path in a process | | >0 | >0 | Yes |
| | Average number of resource types used per path in a process | | >0 | >0 | Yes |
| Resource | [similar to resource type key indicators] | | | | |
| Business Object | [similar to resource type key indicators] | | | | |

The possibility of identifying and formalizing structural weakness patterns is necessary for effectively automating the identification of weak process structures and for benchmarking. Automatically identifying potential weaknesses with the help of quantitative key indicators offers an effective possibility of analysis (proposition P3). However, a subsequent manual crosscheck is necessary to ensure semantically correct results as the automatic detection only provides "potential" weaknesses but not necessarily "real" weaknesses. Nevertheless, the automatic (pre-)analysis can unburden modeling experts and process owners in their struggle of improving the processes very much.

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 structural weakness patterns are defined and formalized. Identified problems 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. Generally speaking, it is best to characterize weaknesses with as much detail as possible and also to formalize as many of these characteristics. Following the actual set of structural weakness patterns, this also means defining more complex weakness patterns (e.g. combining several elements of a process modeling language to a complex pattern) in a next evaluation step compared to using simple patterns (e.g. patterns that are made of only one or very elements of a process modeling language) to increase effectiveness (precision) of the presented approach. This will help to find more complex and thus more hidden potentials automatically through defining process-spanning weakness patterns in combination with more complex pattern combinations.

So far, this article has only concentrated on structural weakness patterns. Hence, only syntactic elements of the SBPML notation were at the core focus. Regarding the inherent semantics of the language, it is also possible to automatically identify semantic weaknesses (e.g. information deficits, media breaks that can only be uncovered when an algorithm understands the actual semantics of a process model and thus the real world fact that is actually depicted in a process model). The identification of such patterns especially depends upon how well and formalized (e.g. using a standard vocabulary) the processes have been documented. However, this is not part of this research contribution.

Going into more detail, there are further limitations of the presented automatic structural weakness identification approach. For example, in this article only one complex and large business process model with various sub processes and a limited set of weakness patterns was analyzed, so that the results can just be seen as a first indicator of the potential of this approach for weakness analysis.

# 7. CONCLUSION

With respect to this article's contribution to the body of knowledge, design research was conducted according to the design research guidelines, defined by Hevner et al. [34], by creating an innovative and purposeful artifact for a pattern-based automated analysis of structural weaknesses in business process models. By developing, applying and evaluating the approach, a research artifact was provided through the application of a rigorous design science research cycle. By applying the approach in practice, it turned out that the modeling and especially automated analysis approach is highly relevant to the domain of banking and offers much potential for the identification of structural weaknesses and hence for improvements in banking processes. The approach allows a flexible, fast and automatic evaluation of SBPML models, based on identified weakness patterns, not only by modeling experts, but also by decision makers.

Thus, it was possible to use the advances in business process modeling languages to combine and formalize traditional approaches to business process analysis and extend these to in-depth process and activity-based analysis. However, as argued with respect to the limitations, the methodology for business process analysis is only as good as the people who use it and it significantly depends upon the careful definition and interpretation of structural weakness patterns. In addition, this approach is arguably not limited to the financial sector only, but may well also be applied to process models from different industries.

The approach is not limited to the used SBPML notation but can also be adapted and used in combination with other process modeling languages. Furthermore, more complex languages may allow for a more sophisticated analysis, since more elements or element combinations can be used for identifying quantitative key indicators. As a result, this article has provided a valuable research contribution for benchmarking and weakness identification. Nevertheless, future research in the area of how to define weakness patterns with as much detail as possible is suggested. In addition, research on creating a detailed taxonomy of the different types of structural weaknesses, which are to be found in business processes of banks and even in general in different industries, is recommended. Finally, research on applying the enhanced business process analysis methodology in the context of more cases, different industries and even different process modeling languages is recommended to prove the generality that is assumed in this approach. Giving an outlook on what more potential the idea of automatically identifying structural weaknesses in processes has, it also seems to be imaginable that it can be possible to automatically suggest reorganization patterns / alternatives for improving identified weaknesses to a certain extent.

# 8. ACKNOWLEDGEMENTS

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