

A Practical Extension of Frameworks for Auditing with Process Mining

Ella Roubtsova¹ and Niels Wiersma²

¹Open University of the Netherlands, The Netherlands

²Municipality Eindhoven, The Netherlands

Keywords: Audit, Audit Statements, Compliance Patterns, Frameworks for Audit with Process Mining.

Abstract: Audit of processes to verify legal compliance is a necessary activity in banks, municipalities and many other sectors. In theory, by using log-files and process mining tools, auditors can automate the auditing process instead of data gathering and taking samples. However, audits are rarely supported by process mining tools in practice. This paper investigates the reasons for that. We identified the fact that the published audit frameworks with process mining are not oriented on real auditors. They replace the auditors with compliance experts and do not see the necessary steps of refinement of audit statements to make them useful both for writing process mining filters and for analysis of the process instances on correspondence to audit goals and policies. We also identified that the building or correcting business process models for audit is often driven by the log information.

On the basis of our findings, we propose an extension of the audit frameworks with process mining and evaluate our extension by conducting case studies of audit in different business domains.

1 INTRODUCTION

Auditing is a standard business practice with many applications. Traditionally, the first thing that comes to mind when thinking about auditing is a financial context, aimed at examining compliance of a business to tax rules and regulations. This is only one of many uses. Today, one can audit maintenance engineering practices, health and safety issues, ethical conduct, and a wide variety of IT-related practices such as information systems security and access control (Jans et al., 2013; Jans et al., 2014; Accorsi and Stocker, 2012).

An audit can be defined as an “independent and documented system for obtaining and verifying audit evidence, objectively examining the evidence against audit criteria, and reporting the audit findings, while taking into account audit risk” (Karapetrovic and Willborn, 2000). Process audit is one of many audit types, which is aimed at the auditing of a specified business process against documented procedures. According to (Russell, 2006) business process audits are used to measure conformance to standards and requirements of the product that is delivered through the process. Another objective of audit may be measuring the effectiveness of the process and the instructions that deliver the product.

When introducing the research field of process mining, (van der Aalst, 2011) presented the extracting of knowledge from event logs of information systems as an opportunity to discover processes, check conformance of processes against a predefined model and enhance models. Recently, the necessary techniques have implemented in the ever-increasing number of process analysis tools, such as (DISCO, 2016), (ProM, 2016), (bupaR, 2017) and many others. Still, process mining is rarely used for audit in practice.

This paper analyses the reasons, identifies the missing steps and proposes a practical extension for auditing frameworks with process mining. The proposed extended framework is validated by two case studies of audit of a grant application process and a process of handling invoices.

The structure of the paper is the following. Section 2 describes related work, including process mining, audit statements, conformance patterns and existing frameworks for audit with process mining. This section contains our findings about possible reasons of rare practical use of process mining for audit in practice. In Section 3 we propose a practical extension for auditing frameworks with process mining. Section 4 contains results of two case studies aimed at evaluating the proposed extension. Section 5 discusses the results of evaluation of the proposed extension

and invites applying the proposed extension for existing frameworks for future work.

2 RELATED WORK

2.1 Process Mining

Process mining is defined as the activity of discovering, monitoring and improving real processes by extracting knowledge from event logs that are present in Information Systems (van der Aalst, 2012).

Central to process mining is an event log, which contains log entries of events that are captured by an information system.

Each entry of a log presents an event and consists of at least the following information: (*case designation, activity label, time stamp*). In practice, logs may contain more information; so an event can be presented as an instance of a tuple (*case designation, activity label, time stamp, resource, performer, product description, order size...*).

An event log of a process can be seen as a record of all events of all cases of the process within a certain time interval. Each case is a sequence of events.

There are different types of process mining (van der Aalst, 2011):

- Process mining may be organized as a process discovery from a log. “For example, well-known algorithms such as the Alpha algorithm can automatically extract a Petri net that gives a concise model of the behavior seen in the event log. This gives the auditor an unbiased view on what has actually happened” (van der Aalst et al., 2010). The model extracted from a log may be too detailed for the level of abstraction needed to the auditor.
- Process mining may be organized as model conformance checking that uses a predefined process model and compares this model with the data in the event log. By doing this, one can answer questions regarding conformance of a real-world process as recorded in the event log to the model of the process as it should be. A predefined model is a prerequisite for conformance checking.
- Process mining may validate the compliance of a logged process with the rules specified for a given business process. Compliance with various laws, regulations and standards is a well known problem in business process development and management. The compliance can be checked at the design time (Awad et al., 2009) and at run-time (Barnawi et al., 2016).

2.2 Process Audit, Audit Statements

Such process mining types as process discovery and conformance checking do not completely correspond to the process audit in its traditional sense.

Process audit in practice is defined as obtaining evidence that a process is in compliance with predefined rules called audit statements. Practical audit usually does not demand the existence of a given business process model, as some adhocery and adaptivity are considered acceptable (Mintzberg and McHugh, 1985). Practical audit is executed unexpectedly or periodically. It’s major goal is to find evidence of violations of predefined rules and possibly find the reasons of violations (Karapetrovic and Willborn, 2000). The audit evidence is often obtained manually, by conducting interviews with user about the process they follow, or taking samples of cases that are executed in the system. This evidence must then be compared against documented procedures. The documented procedures can be presented as a number of written rules and regulations called audit criteria that pertain to the business process and should be observed while executing it (Karapetrovic and Willborn, 2000). In other words, the whole business process is usually not specified in the documented procedures of audit.

Process audit risk influences the scope of audit statements. The auditor focuses his or her effort on formulating audit statements in the areas where most risk is perceived. The risk is calculated as a function depending upon the number of cases (process instances) that non-compliant with the audit statement, and as the financial loss associated with all non-compliant cases.

Audit statements specify the important rules as principles which are not ready for process mining as they do not name the process activities and data items in the log structure.

For example, a simple ordering based rule is specified as “no change to a request can be made after it is approved” (van der Aalst, 2011). In order to automate the compliance checks to this rule, the auditor needs some knowledge or assumption about the business process activities that can be found in the log. She can assume that there are activities “Order Approved” and “Request Order Change”. The auditor should see a case as a sequence of events where the activities have ordering relations, say one activity can follow another. If these assumptions are made, then the audit statement can be formulated as: “Activity *Order Approved* must never be followed by activity *Request Order Change* (for the same Order)”.

2.3 Compliance Patterns

Audit statements are the rules that should be checked for the business process under the audit, so the classification of rules as process compliance patterns used by the compliance checking (Ly et al., 2013) is applicable for audit.

The compliance patterns have been conceptually presented in (Barnawi et al., 2016). A compliance pattern is "an abstract specification of monitoring requirements and it covers the major structural facets of business processes: (1) Occurrence, (2) Order (with or without time span) and (3) employed resources" (Barnawi et al., 2016).

The group of Occurrence Patterns presents Existence or Absence of activities with given values of process data.

The group of Order Patterns often includes the time span information and presents a sequence of actions often with time stamps to define a time span, a precedence or a response.

The group of Resource Patterns presents Binding Of Duty, Segregation of Duty or Responsibility (Performed By). This group is often called Agent Based.

There is a group of Product Patterns that names the states of the products handled or produced by the business process.

The compliance patterns can be logically composed. In general, a process compliance pattern is an expression supported with the temporal logic that informally means "there are (or there are no) cases where an Order Pattern defined on activities is met, and(or) the Time Span between activities is within the norm, and(or) the given Resource was used and(or) by the given Role, and(or) the specified Product is produced (or ordered) ..." (Roubtsova, 2005).

The concept of anti-patterns (pattern negations, or negation of sub-expressions of a pattern) can be also used as the process instances that violate the rules are the target of audit (Barnawi et al., 2016).

Compliance patterns are implemented in process mining tools as log-filters.

The role of an audit statement in audit with process mining is twofold. On the one hand, an audit statement is an instantiation of a compliance pattern or a composition of patterns. On the other hand, an audit statement is a means of communication of experts with different backgrounds. So, the replacing the formal expression of audit statements with expressions in a Controlled Natural Language (Spreeuwenberg and Healy, 2009) should definitely support analysis of audit results. A Controlled Natural Language preserves the terminology used by auditors and business process experts and preserves the structure

of compliance patterns in expressions of audit statements.

2.4 Existing Frameworks for Audit with Process Mining

The existing frameworks for audit with process mining assume that the business process model is given or is built for the audit. It is assumed that the audit statements are ready for process mining.

Indeed, the framework presented by (Sadiq et al., 2007) suggests to find a business process model in the log and check the compliance of the logged process with audit statements. The straightforward application of this framework is problematic. The real-world process instances in the event log may not contain the activities and other data mentioned in audit statements.

The framework (van der Aalst et al., 2010) is principally designed to mine and compare de-jure and de-facto business process models.

The BP-MaaS framework (Barnawi et al., 2016) (see Figure 1) for run-time compliance checking supposes that "Business process management practice commences with the Business Expert defining and modelling business process requirements using BPMN. ...The BPMN model follows multiple iterations of design and refinement to faithfully represent business logic and requirements. The outcome is a BPMN model capturing the control and the dataflow of the business logic." The BPMN model is used to filter only cases of the audited process from logs. Another role, is the role of Compliance Expert, who is responsible for formulating audit statements using the compliance patterns.

We may evidence the presence of Business Experts in the practice of iterative building of a process model suitable for audit. However, we do not agree that each company has a Compliance Expert. The traditional role of an Auditor, who formulates audit statements as principles and may be not acquainted with compliance patterns and details of the business process, is not present within the BP-MaaS framework.

We observed the roles of an Audit Expert, and an IT Expert involved in organizing an audit with process mining. This observation has led us to a proposal of an extension for frameworks for audit with process mining.

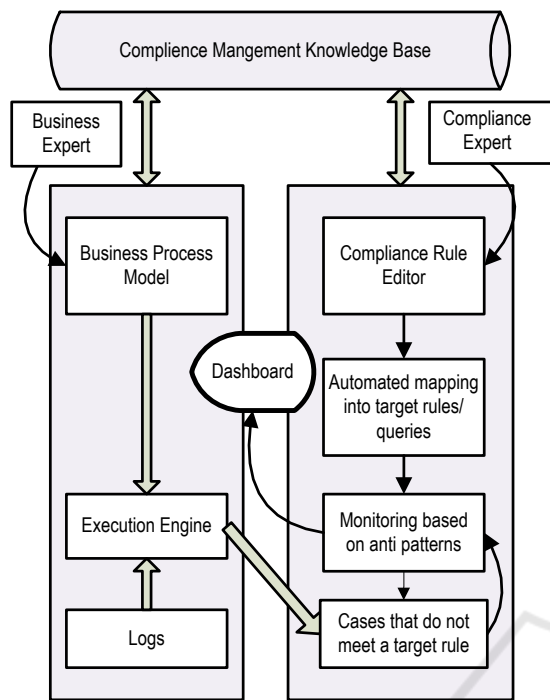


Figure 1: BP-MaaS framework for run-time compliance checking.

3 AN EXTENSION FOR FRAMEWORKS FOR AUDIT WITH PROCESS MINING

The practice shows that the auditors see the audited process abstractly, see only important principles. The auditors often use different terminology than the terminology of business process experts. Audit statements almost always need refinement to the process activities existing in a business process and recorded in logs.

However, the logs usually record activities of many business processes. Moreover, the names of activities in the logs may deviate from the names used by business experts (for example, they may be abbreviated). Sometimes one business process is recorded in different logs. So, the logs need to be prepared and filtered for the audited business process.

The research question of this work is the following: *What steps should be included into the frameworks for audit with process mining to relate the audit statements formulated by Audit Experts, the business process known by Business Experts, and the logged process activities available for IT Experts, and enable audit with process mining?* We have found in the literature a recommendation that “A participatory

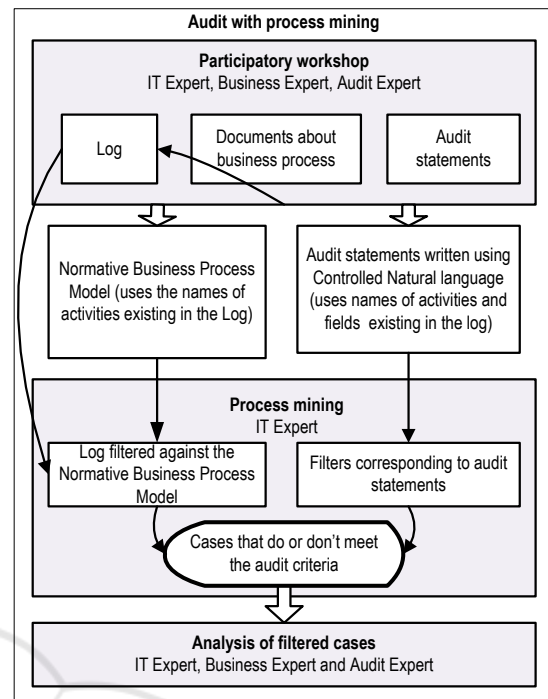


Figure 2: Our Extension for Frameworks for Audit with Process Mining.

modeling workshop is appropriate for the situations where the facilitated modeling with a group of stakeholders is crucial for the implementation of new business technology. It is particularly useful when an agreement and solution can be completely covered if all stakeholders participate in discussion” (Sandkuhl et al., 2014).

We propose to extend the frameworks for audit with process mining with a participatory workshop to relate terminology of three groups of experts. Figure 2 shows our extension for audit with process mining with a participatory workshop. The expected results of the workshop are a Normative Business Process Model and a set of Audit Statements written in a Controlled Natural Language. The process and the statements should use names of activities and fields existing in the log.

In the next section, we report the evidence of the necessity and usefulness of such an extension in two case studies of audit with process mining in different business domains.

4 EVALUATION OF THE PROPOSED EXTENSION

We have conducted two case studies in different business domains in order to show evidence that

- the audit criteria formulated by Audit Experts need refinement allowing one to relate them to the process activities;
- the event logs often do not contain the names of activities used by Business Experts for process description;
- audit with process mining needs a participatory workshop combining an IT Expert, a Business Expert and an Audit Expert. The workshop should create a model of the Normative Business Process with the names of activities used in the log. The workshop should reformulate the Audit statements in a Controlled Natural Language that uses the names of activities from the Normative Business Process, and phrases indicating ordering of activities, resources and other concerns used in compliance patterns.

The validation of the results of a participatory workshop is presented as the number of audit statements formulated after the proposed steps and checked with process mining techniques.

4.1 Audit of a Grant Application Process

The process description found in documentation was rather informal.

In the process of grant applications, citizens or local institutions apply for a monetary allowance provided by the city. This is called a grant, and can be used to organize an (yearly or one-time) activity that contributes to the communal goals that the city has defined. Grants can be awarded for several small-scale goals, such as sporting events and local festivals, but also large grants for welfare support of special-interest groups are issued.

A grant application should be sent within the deadline. After that it is examined, additional information may be requested. All steps of the application and examination should be done in predefined time slots. After all the examinations, a grant can be awarded or the application can be rejected.

4.1.1 Initial Log

To obtain the log, an IT Expert exported the log, translated metadata, anonymized data and imported the log into the process mining application. The log was then

filtered for year of grant 2014, as this was fully contained in the exported time period of 2011 – 2015. The csv-file (comma-separated values) of the log was loaded as a spreadsheet. There were found 132 unique events (activities) that are part of the grant application process. The log contains the following fields: (1) *Case Number*, (2) *Case Description*, (3) *Year of Grant*, (4) *Amount requested*, (5) *Amount granted*, (6) *Grant Regime*, (7) *Grant Type*, (8) *Date of payment*, (9) *Activity name*, (10) *Resource name (anonymized)*, (11) *Activity date(time)*.

The deviation of the informal process description from the log structure is already recognized. For example, it is not clear what "Grant Type" and "Grant Regime" mean. The process description does not contain names of process activities.

4.1.2 Control Objectives and Audit Statements

We have observed, that an Audit Expert begins his work with control objectives. A control objective is a generic statement that is applicable on the entire domain of a law or regulation. Among such objectives are respecting the deadlines, classification of cases, prioritizing of particular properties of a process case.

In order to support process mining, any control objective should be formulated in terms of the audited business process. However, the business process was informally defined. So, the first versions of 52 audit statements found in documents were also rather informal. We present examples of the initial audit statements.

- *ST1* : Every grant application is required to be submitted on time.
- *ST13* : The activities that will be executed if the grant is approved must be described in a SMART manner.
- *ST14* : During the grant approval process, the financial review and content review cannot be performed by the same employee.
- *ST25* : If the grant amount that is approved is larger than 50.000EUR, a semi-annual progress report is required by July, 1st at the latest.

Analyzing these audit criteria, one can think of activities that can be presented in the log, like submission, approval, review, progress report. However, one can never be sure, if these names of activities are present in the business process and the log. An agreement on a "normative process" should be achieved in the organization between business process experts, IT experts and auditors, so that the audit can be fulfilled and its results can be interpreted.

The facts presented in sections 4.1.1 and 4.1.2 show the evidence that a participatory workshop was needed.

4.1.3 Normative Process as a Result of a Participatory Workshop

A participatory workshop was organized. The first purpose of the workshop was an agreement on a normative process, containing the activities found in the log.

First, the experts agreed on the grant application process shown in Figure 3. It contains 11 activities and the end-state of grant allocation.

However, during the workshop, the Business and IT Experts identified that each decision point of the normative process shown in Figure 3 in reality has more outcomes. A grant may be approved, rejected, partially approved, approved with a sanction etc. When the real normative outcomes were listed, the normative process recoded in the log was filtered with the help of the Disco tool. It contains 56 activities (see Figure 4). In the Disco tool, the colour intensity of the activity corresponds to the frequency of its use in cases (process instances). So, the grey activities are used in a smaller number of cases than the dark blue activities. The names of activities and the frequencies of their use were zoomed in and the list of real activities was corrected.

4.1.4 Audit Statements in Controlled Natural Language (CNL)

Using the names of activities found in the log and the ordering of activities in the normative business process, the 52 audit statements were revised and reformulated to be used in the process mining tool. We present examples of audit statements. All statements can be found in (Wiersma, 2017).

For example,

ST1 (informal): Every grant application is required to be submitted on time.

got the new formulation:

ST1(CNL) : For every case where the grant regime equals “average” or “large”, the timestamp of activity “proposal received” must be earlier than 31-10-2013.

Another example:

ST7 (informal): If a request to supply missing information has been sent to the applicant, the missing information need to be provided by the applicant within 10 working days.

ST7 (CNL): For every case if the activity “DI datum request missing information” is executed, the time between this activity and the activity “Receipt of missing information” must be < 14 days (the weekends have been added).

There is a statement corresponding to the the so-called four-eye principle.

ST48 (informal): During the grant application process, the financial review and content review cannot be performed by the same employee.

ST48 (CNL): For all cases where activities “review context” and “review financial part” must be reviewed by two different resources.

Some audit criteria specify the details of specific cases. For example,

ST36 (informal): Grants > 100.000 must submit an accountant statement.

ST36 (CNL): For all cases where the attribute “amount received” > 100.000, activity “additional information received” must contain an accountant statement.

Some audit criteria were used to correct the normative process. For example, it was found that two reviews (context and finance) were required to be performed in the real process.

S11: Every application is reviewed with respect to content by the grant expert. The review is documented.

S12: Every application is reviewed with respect to finance by the grant account manager. The review is documented.

There were initial audit statements containing events (activities) that were not present in the log. For example:

ST8: For every case where activity “Request additional information” is performed, a notification of suspension is included in the letter. All letters that can be sent to grant applicants are digitally available, and can be checked for inclusion of the suspension notice.

It was found that letters remain a human one-time activity and not reflected in the log.

There were audit statements that could be seen as principles for a group of other audit statements. For example, “*ST47: The activities that will be executed if the grant is approved, must be described in a SMART manner*”. *ST47* is a principle for a group of audit statements “that will be executed if the grant is approved” to be Specific, Measurable, Assignable, Realistic and Time-related.

4.1.5 Results of the Audit with Process Mining

In total, 27 statements out of 52 were made suitable for process mining. This shows the degree of audit support that can be achieved with process mining. In case of the design of logs of processes for automated audit, the degree of support can be increased.

Results of the audit with process mining are the following. 23 of 27 filters of all verifiable audit statements did have one or more non-compliant cases that were included in the event log. In the Disco-tool, the

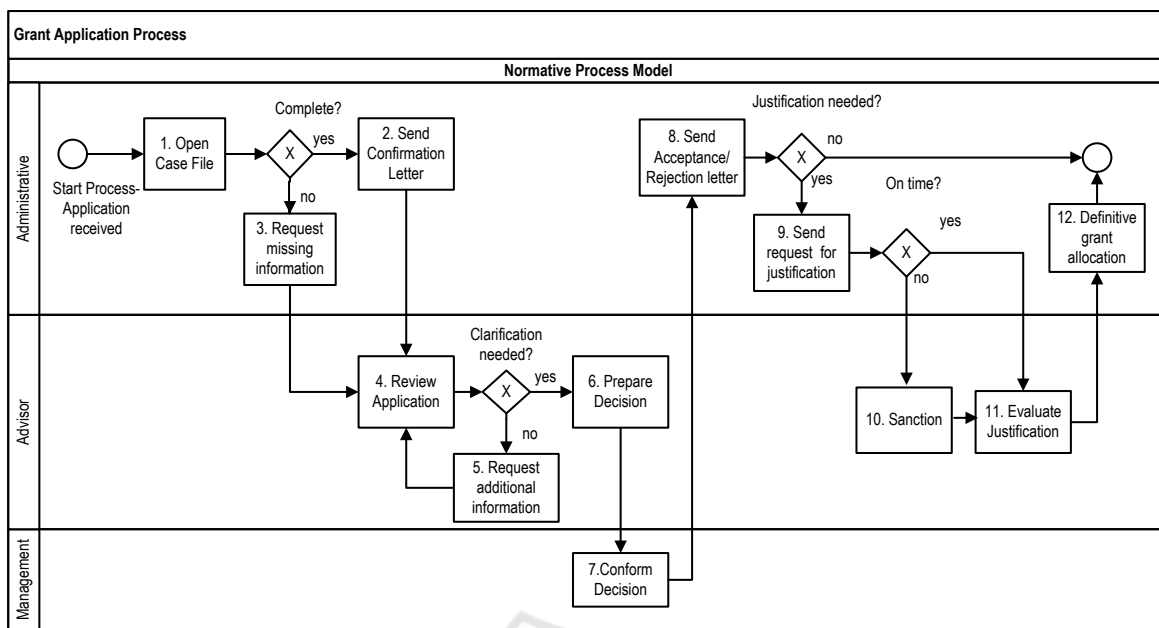


Figure 3: Initial Normative process.

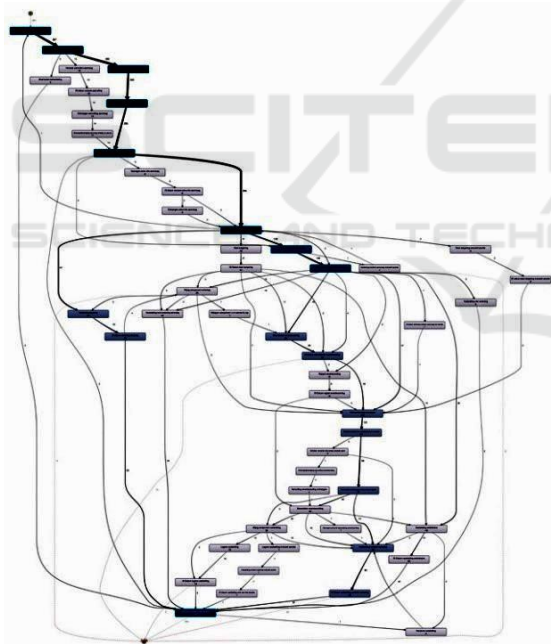


Figure 4: Corrected grant application process.

non-compliant cases can be visually identified by applying the appropriate filter for the audit statement.

For example, after application of the *ST7* filter (about deadlines for receiving missing information), the process map, containing four cases, can be analyzed to find the reasons of non-compliance (Wiersma, 2017).

ST7 has four cases that are non-compliant. Is

this good or bad? This depends on the risks associated with compliance to this statement. The analysis should be done by the Audit and Business Experts.

4.1.6 Results of the Case Study

The audit of the Grant Application Process has shown evidence that a participatory workshop is the key step to the success of frameworks for audit with process mining.

In the participatory workshop, the business model described by business experts was corrected by confronting with the activities recorded in the log. Audit statements were rewritten using the names of activities in the log, and the norms used in the business process.

After such preparations, the process mining was used for compliance checks of the business process to the audit statements.

4.2 Audit of a Process of Handling Invoices

The second case study was conducted in a financial department, because the processes in this domain are a subject to law regulations and have guidance proscribed by the national professional accountants organizations, like, for example, (PAiE, 2017).

The question was if the identified need for a participatory workshop depends on the domain of audit.

4.2.1 Evidence of the Need of a Participatory Workshop

An organization uses services and purchases goods. The service and goods providers send invoices as requests for payment for certain goods or services. The handling of purchasing invoices is a financial process.

We have found the following sources with some elements of the process model: (a) a process breakdown in a table of statements that is used by the internal auditors; (b) a user process instruction for specific roles.

We have collected the initial information about process activities, their relation to business roles and logs in a table (see Figure 5) to present it during the participatory workshop. Figure 5 shows the absence of a well-described business process model of the audited process. The found audit statements were in the form of control objectives. A participatory workshop was needed.

4.2.2 Results of a Participatory Workshop

One result of the participatory workshop was a Normative Process. The limited space for the paper does not allow us to present it. The process can be found in (Wiersma, 2017).

Another result is the 55 audit statements (Wiersma, 2017). Following our framework extension, the statements were rewritten for compliance checks using a Controlled Natural Language. We faced with the fact that not all 55 statements were unambiguous. For instance, statement *ST5.1* is ambiguous:

ST5.1. Imported invoices are rerouted to employees that can select the department for further processing of the invoice after the necessary information is added.

Our sources contained no further information that could be used to assert which data is considered necessary.

The participatory workshop has shown that no log of the *Purchasing Invoices Process* is available. The Purchasing Invoices Process workflow is implemented in the OpenText eDocs Document Management System, which is used by all departments. In addition to this system, the scanning and processing of received invoices was done in a KTM (Kofax Transformation Module) application. Finally, the actual payment order to the bank is processed by the financial system. Logging of this system was available for auditing, but was too complex to integrate in the audit. To obtain the event log of the invoices workflow, IBM Cognos BI was used to select and export the data from the eDocs Document Management System. For this

case, a selection is made based on the time stamps of case activities in eDocs with date values between 01 – 01 – 2015 and 31 – 12 – 2015.

Even in the found log, not all audit criteria could be transformed into a filter of a process mining tool, because the log did not contain necessary information. The first two activities of the process (scanning and importing) are not part of the activities in the event log as these are performed in a different system. As a result, we could use only 11 out of 55 audit statements for the process mining and finding the compliant and non-compliant cases.

5 RESULTS AND CONCLUSIONS

In this work, we have evaluated the upcoming technology of audit with process mining.

Analysing the literature, we have found frameworks for audit with process mining that assume existence of business experts with the knowledge of a business process model, and compliance experts, who are able to formulate audit statements applicable for process mining tools.

Conducting the case studies, we have found that the companies more likely have IT Experts, Audit Experts and Business Experts. The success of application of process mining for audit depends on agreement on terminology achieved by these three groups of experts. We assumed that this agreement can be achieved in a participatory workshop.

We have proposed to include such a workshop in any practical audit framework with process mining in order to manage the expectations of businesses, that plan to apply process mining for audit.

We have applied an extended framework in two case studies in different business domains and succeeded to design the normative business processes and audit statements that can be used for compliance checks on logs.

Both case studies have evidenced that the direct application of process mining for audit is a too large step that cannot be made by the business without intermediate steps of designing the normative business processes and audit statements applicable for process mining on the process logs. In our first case study, the business process model provided by business experts was corrected by extra outputs of decisions. The correction came from the log analysis. In the second case study, the business process model was created from a table of partial descriptions of process steps.

Both of our case studies have evidenced that such a business role as "Compliance Expert" does not exist and the initial audit statements made by Audit Experts

Nr	Name	Description	Role	Activity in log
1.	Scan invoice	Incoming invoice (by mail) is scanned as part of a batch of invoices	Department Invoices	None (Kofax system)
2.	Check / complete scanned invoice	The text on the invoice is automatically recognized (OCR) and translated to specific fields: date on the invoice, invoice no., bank account number, commitment number and amount payable. The result of the OCR is visually checked against the digital scan (and completed / corrected)	Department Invoices	None (KTM system)
3.	Send invoice to DMS	The invoice is exported from KTM and imported into the Document Management System (eDocs)	Department Invoices	Purchasing Invoices 2.0
4.	Complete invoice details	The fields required for further handling that were not imported are completed: invoice description, tax code and amount, department to authorise, number of supplier (looked up in Decade)	Financial data entry	Purchasing Invoices 2.0
5.	Invoice at block manager	The invoice is sent to the block manager for re-routing to the department	Financial data entry	1.Invoice at block manager
6.	Re-route to department	The block manager re-routes the invoice to the department for authorization	Block manager	2.Receive and reroute
7.	Encode invoice	The invoice is re-routed to the right resource for the performance check, to verify that the goods that are billed are delivered.	Department inbox	3.Encode invoice
X	Correctly Booked?	If the department thinks the invoice is incorrectly put in their inbox, it is rerouted back to the block manager.		
8.	Performance check	The performance check is executed by sending an 'OK' and a comment in the eDocs system. This step is not enforced and sometimes skipped.	Checker	4.Performance check
9.	Encode invoice	The booking details (cost centre and booking combination) are entered.	Department inbox	3. Encode invoice
10.	Check booking details	The invoice is sent to a resource that checks the booking details. This step can be skipped	Checker	5. Booking entry check
11.	Approval	The invoice is approved by the budget administrator (in case of a commitment already exists in Decade) or the budget manager. Approval is done for each invoice line.	Budget admin / budget mgr.	6. Approve invoice
12.	Authorize payment / process invoice	The complete invoice and payment details are checked and payment is authorised. After authorisation, the payment is automatically processed by Decade.	Financial advisor	Process invoice

Figure 5: Table for the Participatory workshop.

should be rewritten for process mining by an IT expert in collaboration with an Audit Expert and a Business Expert.

So, the cases demonstrate usefulness of our proposal to include a participatory workshop into audit frameworks for audit with process mining. They also show the types of artifacts that are created by the participatory workshop: a Normative Business Process Model using the activities mentioned in the log and a set of Audit Statements formulated in a Controlled Natural Language. A Controlled Natural Language uses the activities mentioned in the log and the compliance patterns that can be checked in the log by pro-

cess mining tools.

The construct validity of our case studies is guaranteed by the many sources of information used for conduction of them (triangulation). Indeed, any business model and statement was inspected by three different specialists using different documents.

The conduct validity of our case studies can be checked by everyone as we have presented the steps of the proposed framework and results for research reproduction, as it is recommended in literature on case studies (Yin, 1994). All details about case studies can be found in (Wiersma, 2017). The logs can be provided on request.

Although we used the Disco tool for process mining, our extension is tool independent and can be applied for the frameworks that work with different process mining tools.

As future work, we invite using our extension for audit frameworks with process mining. This may result in a reusable collection of normative business processes and audit statements for specific domains of audit application.

REFERENCES

- Accorsi, R. and Stocker, T. (2012). On the exploitation of process mining for security audits: the conformance checking case. In *Proceedings of the 27th Annual ACM Symposium on Applied Computing*, pages 1709–1716. ACM.
- Awad, A., Weidlich, M., and Weske, M. (2009). Specification, verification and explanation of violation for data aware compliance rules. *Service-Oriented Computing*, pages 500–515.
- Barnawi, A., Awad, A., Elgammal, A., Elshawi, R., Alma-laise, A., and Sakr, S. (2016). An anti-pattern-based runtime business process compliance monitoring framework. *framework*, 7(2).
- bupaR (2017). Business Process Analysis in R. <http://bupar.net/>.
- DISCO (2016). Flexicon DISCO. <http://fluxicon.com/disco/>.
- Jans, M., Alles, M., and Vasarhelyi, M. (2013). The case for process mining in auditing: Sources of value added and areas of application. *International Journal of Accounting Information Systems*, 14(1):1–20.
- Jans, M., Alles, M. G., and Vasarhelyi, M. A. (2014). A field study on the use of process mining of event logs as an analytical procedure in auditing. *The Accounting Review*, 89(5):1751–1773.
- Karapetrovic, S. and Willborn, W. (2000). Generic audit of management systems: fundamentals. *Managerial Auditing Journal*, 15(6):279–294.
- Ly, L. T., Maggi, F. M., Montali, M., Rinderle-Ma, S., and van der Aalst, W. M. (2013). A framework for the systematic comparison and evaluation of compliance monitoring approaches. In *Enterprise Distributed Object Computing Conference (EDOC), 2013 17th IEEE International*, pages 7–16. IEEE.
- Mintzberg, H. and McHugh, A. (1985). Strategy formation in an adhocracy. *Administrative science quarterly*, pages 160–197.
- PAiE (2017). Professional Accountants in Europe. <http://paie.nl>.
- ProM (2016). Process mining Workbench ProM. <http://www.promtools.org>.
- Roubtsova, E. E. (2005). Property driven mining in workflow logs. In *Intelligent Information Processing and Web Mining*, pages 471–475. Springer.
- Russell, J. (2006). Process auditing and techniques. *Quality Progress*, 39(6):71–74.
- Sadiq, S., Governatori, G., and Namiri, K. (2007). Modeling control objectives for business process compliance. *Business process management*, pages 149–164.
- Sandkuhl, K., Stirna, J., Persson, A., and Wißotzki, M. (2014). Enterprise modeling. *Tackling Business Challenges with the 4EM Method*. Springer, 309.
- Spreeuwenberg, S. and Healy, K. A. (2009). Sbvsr approach to controlled natural language. In *International Workshop on Controlled Natural Language*, pages 155–169. Springer.
- van der Aalst, W., van Hee, K. M., van der Werf, J. M., and Verdonk, M. (2010). Auditing 2.0: Using process mining to support tomorrow's auditor. *Computer*, 43(3).
- van der Aalst, W. M. P. (2011). *Process Mining - Discovery, Conformance and Enhancement of Business Processes*. Springer.
- van der Aalst, W. M. P. (2012). Process mining: Overview and opportunities. *ACM Transactions on Management Information Systems (TMIS)*, 3(2):7.
- Wiersma, N. (2017). The use of Process Mining in Business Process Auditing. <http://hdl.handle.net/1820/7702>. Open University of the Netherlands.
- Yin, R. (1994). Case study research: Design and methods . beverly hills.