An Application of Process Mining to Invoice Verification Process in SAP

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Abstract. There are many processes in companies that are enacted many times every day. The key issue of the company management is to control the company cash flow and try to optimize the cost of everyday operations. There are many ways how to support the process enactment, but at the end, when there are some data from the process usage, the analysis of the efficiency is needed. One of the ways how to analyze the process and effectively analyze the process data is to use process mining methods. In this paper, we present the usage of process mining methods to real invoicing process and show the possible impact of the results to the process or organizational improvement.

Keywords: process mining, case study, SAP, process improvement.

1 Introduction

Companies enact most of their key business processes with the support of information systems. Enacted processes are represented by workflows, partly managed by the information system, partly managed by users' decisions and activities. It is not easy to understand whether the specific process runs efficiently, because usually many various activities are processed in parallel and process definition allows plenty of process enactment variations. Our task was to analyze specific process with request to suggest steps for its simplification, curtailment and enact the process cheaper.

First of all, we have found that even when processes are enacted in standardized platform (SAP), the requested information for process analysis using process model and monitoring of its enactment is not available. We have decided to apply the process mining approach that use rich information log saved by the SAP within the process enactment. This approach enabled us to start analysis immediately without long term process modeling and implementation phases.

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Our paper is organized as follows: Section 2 introduces the state of the art; Section 3 depicts the experiment that we have performed: describes the data that we have obtained; shows the usage of the process mining methods and explains obtained results and its interpretation in real business; concluding Section 4 provides a summary and discusses the planned future research.

2 State of the Art

In last decades, systems started to be more and more process oriented [1]. The shift to process oriented systems was motivated by the idea of supporting systems to the daily business, to shift the knowledge about operations that could be described as processes from humans to systems. Process oriented systems started to be worshiped as the only way to control the processes and activities that has to be enacted. The knowledge about the processes and their enactment was transferred to the systems.

The shift from the data oriented systems to the process oriented systems brought the companies tools to control and check the enactment of the processes and resources that are involved.

However, to build a quality process oriented system means to build a system supported by workflow system. There are many reasons why this is not always possible, such as a cost, change of doing things very often etc. Thus there are many systems that are process supportive but not exactly process driven like ERP systems (SAP, CRM systems, B2B systems and many other types of information systems). Sometimes these systems are not even aware of the processes that are supported. Processes were not defined at the beginning of the systems implementation or were defined but lost in the long term usage and maintenance of the system.

The need of the proper knowledge about the business data led to the usage of Business intelligence (BI) tools. Since the systems shifted from the data oriented to the process oriented systems, new subdomain of BI, Business process intelligence (BPI), was defined. BPI and its supportive tools help users to manage process execution quality by the analysis, prediction, monitoring, control and optimization [2].

On the other hand, there is a Business process management (BPM). BPM [3] can be defined as whole business company process management and optimization. Its concern is on the process improvement and its alignment to the needs of clients. BPM lifecycle consist of design, modeling, execution, monitoring and optimization. It means that the BPM take care of the composition, enactment and analysis of the operational business processes.

Business process definitions are sometimes quite complex and allow many variations. All of these variations are then implemented to supportive systems. If you want to follow some business process in a system, you have many decisions and process is sometimes lost in variations. Modeling and simulations can help you to adjust the process, find weaknesses and bottlenecks during the design phase of the process. Sometimes you can guess or know the patterns and occurrence probabilities of variations that are used during the execution phase. However, not even modeling and simulation of the processes can tell you, how processes are really enacted in the system, what is e.g. the perceptual usage of the variations and whether some variations are enacted at all. If you want to analyze the real usage of the system, recognize its weaknesses, bottlenecks or strangeness on the real data, you have to know how the process was followed in reality. Process mining is an approach that is used for the analysis of real enactment of the processes. Process mining uses logs of real process enactments to analyze the process itself. Process mining can answer you the question, how the process was really executed, which variations were used and what are the probabilities of the enactment of each process variation. Process mining can be seen as a supportive method for the BP and BPI analysis and from the perspective of BPM, can be used as a feedback to the BPM methods [4].

2.1 Related Work – Case Studies

There is a lot of papers that describe new ways or improvements of methods, techniques and algorithms used in the process mining. Surprisingly only several papers are focused on the case studies, it means, in fact, practical usage of the process mining. Detailed overview of recent case studies up to 2011 can be found in [16]. Authors describe 11 case studies in several domains, mainly in public services [5-15].

Since then, some other papers that describe the usage of process mining where published. In [17], authors applied fuzzy mining, trace clustering and other additional methodologies among ProM to analyze block movement process in shipyards. They used real-world event logs of the Block Movement Control System (BMCS).

In financial sector, authors of [18] used process mining for the identification of financial processes to analyze the compliance to the security requirements needed by the security audit.

In [19], authors demonstrate the applicability of process mining to the discovery of processes that characterize the knowledge maintenance and the organizational perspective is used to find relations between individual performers. This study was made on the real case of a knowledge maintenance process in aviation institute.

The range of process mining case studies and variations of process mining types and methods shows the wide range of process mining applicability to answer different questions in different domains.

3 Case Study

This cases study reacts to a company request to analyze business process of the invoice verification in SAP system with aim to identify context in which the process is not effective and provide a suggestion for the process improvement. The analyzed company runs SAP system in five countries (with five different jurisdictions) and processes approx. 30 000 supplier invoices per year.

3.1 Context

Examined business process of the invoice verification is implemented in SAP ERP and SAP DMS, user activities are controlled by SAP business workflow. Users participate in the invoice verification workflow in several different roles (creator, accountant – completion, approver, and accountant – decision and posting).

Generally, it is process where the accountant should create the invoice, verify it, then send to the approvers and finally when he gets it back he does invoice posting. The case study is about verification of the idea about the process, find deviations and in case of it do retrospective view to the particular instance of invoice verification.

3.2 Data Obtaining and Data Structure

The main task during data preparation was to collect and adjust the application logs to the final structure (see Table 1) needed for the process mining analysis. Data was collected from the workflow system log containing most information about activities. It was needed then to make an adjustment, because the basic log contained the "activity" object that was split between two fields.

The second important step was the anonymization of the data (so that no real name or legible ID is present in the analysis). It is possible to find back the original IDs for essential analysis of the real meaning of results in reality, but with the mapping keys only. Following Table 1 depictures the structure of the adjusted log that we have used for the process mining – we have collected data for all fields, but only mandatory fields were used for the process mining analysis.

Table 1. Data structure of the log

IDOBJ	ID of the invoice	mandatory
IDACTIVITY	ID of the activity	mandatory
DATESTART	Date when the activity started	optional
TIMESTART	Time when the activity started	optional
DATEEND	Date when the activity ended	mandatory
TIMEEND	Time when the activity ended	mandatory
ROLE	Role of the invoice processor (creator, accountant, approver)	mandatory
USER	User account of the invoice processor (real user name)	optional
TRANSACTION	System transaction run by the user during processing the activity	mandatory
DATA	Detailed information about context of the invoice – specifically ORGID, INVOICETYPE, …	optional

We have loaded the log with DATEEND between 1. 1. 2012 - 30. 6. 2012, totally we have loaded **37 991 records** for adjusting.

3.3 Preprocessing of Data

The main task of the data preprocessing was to map records from the application log to the parts of the process in the process mining.

The process in the process mining consists at least of:

- Case – one pass of the process
- Event – one step of the process
- Start time – start time of the task
- End time – end time of the task
- Originator – originator of the particular task

Our log is mapped in the following way:

- Case – IDOBJ
- Event – ROLE + TRANSACTION
- End time – DATEEND + TIMEEND
- Originator - USER

Connection of the ROLE and TRANSACTION allows us to recognize specific activities that are performed by one role in the process. ROLE contains the information which role is performing particular activity (for example accountant). TRANSACTION contains the information about what kind of operation is doing particular role. We have recognized following event classes by the connection of these two attributes:

- Invoice *Creation* (accountant-01) – this event in the real business process means completion of the invoice (scanned originals, completion of all important fields) or recompletion of the existing invoice.
- Invoice *Verification* (accountant-02) – this event verifies the formal correctness of the current invoice (VAT, accounts, …)
- Invoice *Approval* (approver-04) – this event approves the invoice (responsible persons approve the factual correctness of the invoice and approve or reject the invoice, or send the workflow back to the Verification/Creation)
- Invoice *Posting* (accountant-05) – alternative decision of accountant (largely the final posting of the invoice and change of the responsible approver)

There were found some unacceptable records in the log during preprocessing analysis. There were missing mandatory fields of Originator in some records of the log – the reason is that some records were not processed by manual workflow to the end, but were processed by automatic job without updating the application log. We removed these (1279) records and all related records of the particular IDOBJ or case. So at the end, the analysis was performed on **36 711 records**, or respectively events.

3.4 Summary of the Log and Adjustment of Data

The process mining tool ProM 6.2 was used for all analysis attempts [20].

The first step of the analysis was the analysis of the log summary. The log contained **7350 cases** of one process, this means **36711 events**.

The Table 2 describes occurrences, absolute or relative, of particular tasks. Task *Approval* is a most frequented task in the process.

Table 2. Occurrences of all events

Event class	Occurrences (absolute)	Occurrences (relative)
Approval	15524	42.287%
Creation	7669	20,890%
Verification	7344	20,005%
Posting	6174	16,818%

The Table 3 depictures start-event classes of the process. It means start classes that are starting events for at least one of process enactments. The Table 4 depictures end-event classes of the process. It means task classes that are end for at least one of process enactments. Both tables show us that there are event classes that should not start or end the process. It can be caused by some deviations in the process. These deviations of start and end event classes can be target for the further analysis, but in our case, we are sure that correct process starts by event Creation and ends by event Posting every time. It is controlled by the workflow in the SAP, there are no other starts and ends that could be possible. Thus, the only possible explanation in our case is that deviations of start and end event classes are caused by the selection of the time segment from the log for the analysis. Some cases started before 1.1.2012 and some cases started before 30.6.2012 but ended after that date. It caused incomplete cases that have to be filtered. Nevertheless, this can be also analyzed further by other views.

Table 3. Start events

Event class	Occurrences (absolute)	Occurrences (relative)
Creation	7218	98.204%
Posting	122	1,66%
Verification	8	0,109%
Approval	2	0,027%

Table 4. End events

Event class	Occurrences (absolute)	Occurrences (relative)
Posting	5552	75.537%
Approval	969	13,184%
Verification	496	6,748%
Creation	333	4,531%

ProM method Filter log using Simple Heuristics was used for the **filtering** of incomplete cases. There was specified that every case can start only by event class *Creation* and can end only by event class *Posting*. This adjustment of the log caused that log finally contained **5424 cases** and **30784 events** for further analysis.

3.5 Analysis of the Process Characteristics

The final log of examined process without deviations that were caused by data obtaining contained, as was mentioned before, 5424 cases and 30784 events. Occurrence of the event classes is depictured in the Table 5.

Table 5. Occurrences of all events

Event class	Occurrences (absolute)	Occurrences (relative)
Approval	13563	44.059%
Creation	5917	19,221%
Verification	5652	18,360%
Posting	5652	18,360%

Creation and *Posting* are the only start and end event classes, but for the better recognition in the analysis by different ProM methods, artificial events *Start* and *End* were added by the ProM function – Add Artificial Events.

Process Model

Process model is depictured in the figure Fig. 1. We have reconstructed process model from the log by BPMN Analysis (using Casual Net Miner) [22]. Process starts by artificial event Start and then continues by event *Creation.* Next one is *Verification*. These two events Creation and Verification can be done repeatedly. Next, there is a gateway where the *Approval* event can be skipped. *Approval* event can be done repeatedly too. Last events are *Posting* and artificial event *End*.

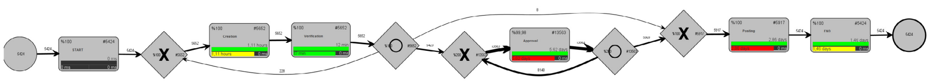

Fig. 1. Process model

The process model shows even the frequency of the transitions between events. It is depicted by numbers next to arcs or by thickness of arcs. When the arc is bolder, then the path is more frequented. We can see the high frequency of regular repeating of *Approval* event. It means that invoice is *Approved* more than once quite often.

Other interesting finding is that *Creation* and *Verification* evens are done always together sequentially.

We have discovered the most frequented paths, respectively all the used paths. Number of all used paths (patterns) is 76. The Table 6 shows summary of the most frequented and most interesting paths that were. Detailed analysis of these most frequent paths is provided in the next section.

Table 6. Interesting paths in the process model

Path	Case(s)	Occurrence (relative)	Number of events
Path 1 – 1st most frequented	2436	44.912%	7
Path 2 – 2nd most frequented	1564	28.835%	8
Path 3 – 3rd most frequented	504	9.292%	6
Path 4 – 4th most frequented	200	1,862%	9
Path 5 – 5 th most frequented – more *Posting* events	101	1,862%	9
Path 6 – most time consuming path	1	0.018%	18
Path 7 – least time consuming path	1	0.018%	10
Path 8 – without *Approval* event	1	0.018%	5

3.6 Analysis of Interesting Paths

This section describes the analysis of most interesting paths that we chose from all paths of the process model.

Path 1 – 1st Most Frequented Path

This path is used by most process enactments (cases) of the log. It is almost the half of all cases. The process model of this path is depictured on the Fig. 2. Process starts by *start* artificial event, continues by *Creation* event, *Verification* event. Next, there are **two** repetitions of ***Approval*** event and process ends by *Posting* event followed by the *end* event.

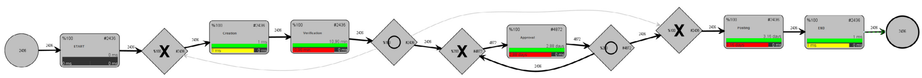

Fig. 2. Process model - Path 1

Path 2 – 2nd Most Frequented Path

This path contains 1564 cases. It is almost 29% of all cases. The process model of this path is depictured on the Fig. 3. Process starts by *start* artificial event, continues by *Creation* event, *Verification* event. Next, there are **three** repetitions of ***Approval*** event and process ends by *Posting* event followed by *end* event.

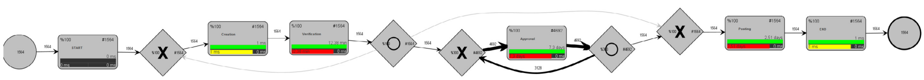

Fig. 3. Process model - Path 2

Path 3 – 3rd Most Frequented Path

This path contains 504 cases. The process model of this path is depictured on the Fig. 4. Process starts by *start* artificial event, continues by *Creation* event, *Verification* event. Next, there is **one *Approval*** event and process ends by *Posting* event followed by *end* event.

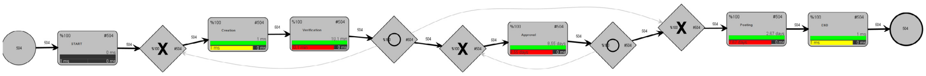

Fig. 4. Process model – Path 3

All three most frequented paths are almost similar. The only one relevant difference is a number of repeats of the *Approval* event. The most frequented path has two, second most frequented path has three and third most frequented path has one repetition of it.

Path 4 – 4th Most Frequented Path

This path contains 200 cases. The process model of this path is depictured on the Fig. 5. Process starts by *start* artificial event, continues by *Creation* event, *Verification* event. Next, there are **four *Approval*** events and process ends by *Posting* event followed by *end* event.

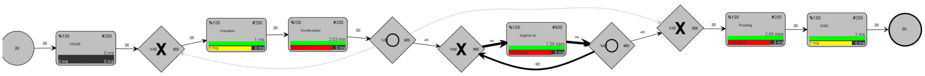

Fig. 5. Process model - Path 4

Path 5 – 5th Most Frequented – More Posting Events

We have chosen this path for detailed analysis because it is fifth most frequented path and contains repetition of *Posting* event. This is some kind of deviation that we are looking for. The path is depictured in the Fig. 6.

Process of this path, or case, is following:

1. *Start* artificial event
2. *Creation* and *Verification* event
3. Two times - *Approval* event
4. *Posting* event
5. *Approval* event
6. *Posting* event
7. *End* artificial event

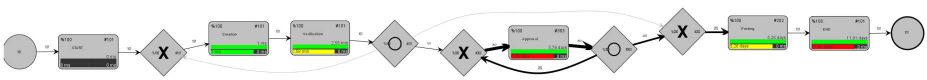

Fig. 6. Process model - Path 5

Path 6 – Most Time Consuming Path

This path is most time consuming path. This path includes only one case. This case was for some reason longest lasting. The path is depictured in the Fig. 7.

Process of this path, or case, is following:

1. *Start* artificial event
2. Two times – *Creation* and *Verification* event
3. *Approval* event
4. *Posting* event
5. seven times - *Approval* event
6. *Posting* event
7. *Approval* event
8. *Posting* event
9. *End* artificial event

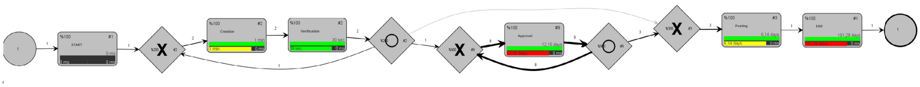

Fig. 7. Process model - Path 6

Path 7 – Least Time Consuming Path

This path is least time consuming path. Same as like most time consuming it includes only one case. The path is depictured in the Fig. 8.

Process of this path, or case, is following:

1. *Start* artificial event
2. Three times – *Creation* and *Verification* event
3. *Approval* event
4. *Posting* event
5. *End* artificial event

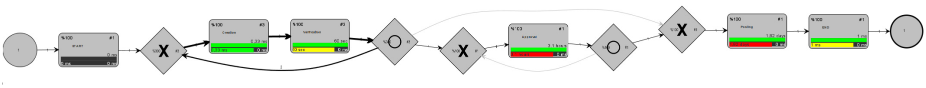

Fig. 8. Process model - Path 7

Path 8 – Without Approval Event

We have chosen this path for detailed analysis because it does not contained *Approval* event. This is some kind of deviation we were looking for. The path is depictured in the Fig. 9.

Process of this path, or case, is following:

1. *Start* artificial event
2. *Creation* and *Verification* event
3. *Posting* event
4. *End* artificial event

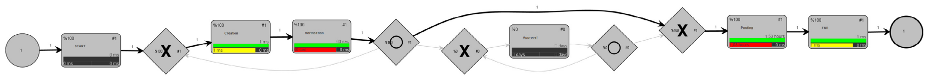

Fig. 9. Process model - Path 8

Time analysis of the Process

There is information about waiting time between events in the process model. It means how much time is consumed by waiting for the completion of previous event. Unfortunately we do not have information about consumed time of particular events - it was not included in the log. So the only information we know is when the events were finished.

3.7 Results and Retrospect to Real Business

We have analyzed following interesting average time parameters:

- Waiting time between *Creating* and *Verification* events is 12 minutes in average. It means that these two activities are enacted almost in the same time. The reason is that these events are performed usually by the same person (accountant).
- Average waiting time between particular *Approval* events is 5,62 days. It is relevant for managers – they will use it for the motivating actors to process the Approval task in shorter time (better monitoring and remainder tool was activated).

We have analyzed specific paths and found the following results:

- **Path 1:** The invoices from this group were found as invoices connected to the purchase order/contract and with proper receipt without differences (amount, price). Typically there are invoices for the investments, strategic raw material and overhead invoices with two persons approving the invoice. This proves that the purchasing system is well defined and settled.
- **Path 2:** Most of invoices from path 2 come from the purchases during main business process and financial services; the confirmation by three persons for specific invoice types was presented with the motivation to find some level of approving during purchasing process and to reduce the number of approvals during invoice verification. The process is mature and correct, the motivation is to move one step to purchase phase where this person is also active.
- **Path 3:** Most of invoices from path 3 come from the purchase in marketing; this testifies maturity of the purchasing along the main business process.
- **Path 4:** This group contains invoices of various types. Most of them contain short discussion between Approvals (request-answer within the meaning of explaining the differences in amount of maintenance service, providing another document …) otherwise they would fall to Path 1. This invoice approval process could be shorten only in case that all information required for invoice approval would be gathered by some “acceptation process – acceptation protocol”. One invoice set in this path has 4 Approval steps based on the organizational structure that is defined in the approving instructions – shortening would mean that theses instructions would have been changed.

- **Path 5:** repetition of the “posting” step always means that the first approver of the invoice refused the responsibility for this invoice (step “not me”). Such decision has mostly reason in assignment of competencies, sometimes in mistakes in invoice classification or other typing error. We can see that although this is the 5th frequent scenario, but occurring only in 1,8% of cases – it is now on managers’ decision if cost of improving will be compensated by benefits. Monitoring of this path is suggested for the future.
- **Path 6:** this is possible (but not typical) enactment for the invoice without purchase order/contract, the purchase order must have been prepared and agreed – it is strictly suggested to have the purchase number approved before the invoice comes (otherwise the invoice is not accepted), this case was combined with issues discussed in Path 5; another case from this group was the invoice from key customer created supposedly pursuant to the contract (there was a long discussion about legitimacy and correctness – but as the partner was strategic partner, the invoice was not turned back and the process was prolonged).
- **Path 7:** very specific invoices with irrelevant amount, high priority verification under control of the company owner, result is irrelevant for other analysis.
- **Path 8:** there was not found any workflow for specific invoices, there are notes at these invoices with link to the documents with confirmation (meeting notes) – it means the invoice was approved by competent person, but out of the workflow system. Such path must be analyzed separately.

4 Conclusion and Future Work

There are some conclusions that we have found about the invoice verification process using process mining techniques.

1. We have found the average values of the running activities, the result about possible time reserves was presented and accepted.
2. The most frequented paths were identified (Path 1, Path 2, Path 3) and business cases along which they occur were found. Analysis showed very frequent approving by three persons (in Path 2) and the business process owner got the material for the process improving.
3. Paths with more than three Approving steps (Path 4) contain communication of some issue during the invoice verification. These cases could be shortened if these identified most frequent issues are part of the acceptation procedure and would be solved before the invoice verification process and the acceptation protocol would be attached by default. Other set of the invoices with four approval steps have this procedure defined by the instructions (only change of the instruction can make the process shorten).
4. Path 5 provides the information about the model of competencies and it is appropriate to monitor this path.
5. The invoices without purchase order have usually longer verification time (the backward purchase order creation takes a lot of time), in some cases it was extremely long (Path 6). These exceptions should not be allowed by default.

6. Very specific cases were found in Path 7 and Path 8 – they do not have any frequent pattern and from this reason are not interesting for conclusion.

This case study opened several tasks for future work. First of all, we have not paid attention to the resources. In future work, we would like to focus also on users, their interaction during the process and construction of their social network

We have been concentrated to most frequent paths with the aim to find reserves and improving themes – in the future, we would like to focus also on deviations (process without expected start and stop event, multiply "unique tasks" as was found in Path 4) this can means some specific problem.

Our study proved that even the basic process mining methods used to analyze the enactment of the processes can be very useful for the real businesses. The processes performed by humans and supported by different systems have often wide range of variability, thus it is not always possible to predict and control the real usage of the process even with the sophisticated system. Thus we have to use information from the real enactments to see what really happened. We can reconstruct the process by the process mining tools; find deviations and other many useful pieces of information by still grooving bunch of process mining methods. This analysis can be then used to improve the process, supporting system or the organizational behavior. Our intention for the future is to study the usage of the process mining methods, find their best value for the business and try to present new methods that can answer the questions that arise from the real business needs.

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