Process Mining for Process Improvement - An Evaluation of Analysis Practices

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Abstract. Organizations have a vital interest in continuously improving their business processes. Process analysts can use process mining tools that provide data-driven discovery and analysis of business processes to achieve this. Current research has mainly focused on creating and evaluating new tools or reporting process mining case studies from different domains. Although usage of process mining has increased in industry, insights into how analysts work with such methods to identify improvement opportunities have consequently been limited. To reduce this gap, we conducted an exploratory interview study of seven process analysts from different domains. Our findings indicate that process analysts assess improvement opportunities by their impact, the feasibility of required implementation, and stakeholders' input. Furthermore, our results indicate that process mining tools, when used to identify improvement opportunities, do not provide sufficient support for analysis, requiring process analysts to use additional tools. Lastly, analysts use storytelling to frame and communicate their findings to various stakeholders.

Keywords: Process mining · Business process analysis · Business process improvement

1 Introduction

Organizations engage in business process management (BPM) to continuously improve their business processes. In doing so, process analysts model the business processes, use a variety of methods to analyze them, and then, based on the results of the analysis, propose and implement changes to the processes [10]. In recent years, process analysts have begun using data-driven methods, such as process mining, to improve processes [8,24]. Therefore, process analysts have begun to incorporate commercial process mining tools, such as Disco[1], Celonis[2], and Apromore[3] in their continuous BPM work [24]. Process mining tools use

[1] https://www.fluxicon.com/disco/.
[2] https://www.celonis.com.
[3] https://apromore.org.

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event logs, i.e., data recorded from process executions, to enable automated discovery of business process models and process analysis [1]. With such data-driven tools, process analysts gain a more complete and accurate understanding of the process execution and save time when discovering and analyzing the business processes [1].

The benefits of process mining for improving business processes have been demonstrated in different industries [24,29], such as logistics [16], manufacturing [27], telecommunication services [20], and auditing [15]. To this end, methodologies for applying process mining, such as PM^2 framework [30], have been proposed. Similar methodologies have also been proposed for specific industries, such as for healthcare [23]. While such methodologies can help process analysts, the analysis conducted to identify improvement opportunities is still manual. Furthermore, methods for applying process mining tools stipulate steps to take and *what* to analyze, but not *how* to analyze. Some studies explore practical aspects of process mining, such as process managers' perception of adopting, using, and managing process mining [13] and how process mining is used by organizations [29]. However, the majority of works mainly consider technical aspects, i.e., development and improvements of process mining techniques [6]. Few studies explore how process analysts use and work with process mining in process improvement initiatives, although the need to research teams and skills needed for successful process mining projects has been highlighted [22]. Thus, there is a gap in how analysts use process mining to identify improvement opportunities, assess which improvement opportunities to pursue, and communicate analysis results to relevant stakeholders.

This paper explores how process analysts working with business process improvement, incorporate and use process mining solutions to discover, analyze, and communicate improvement opportunities. Therefore, this paper's research objective is to explore "*how process analysts work with process mining when engaged in process improvement initiatives?*" In addressing this research objective, we specifically explore three research questions. The first relates to how process analysts use process mining to identify improvement opportunities and which improvement opportunities to address. Process analysts also use process mining to present the findings of their analysis to stakeholders. Therefore, the third research question concerns *how* process analysts use process mining to communicate their findings to stakeholders. To this end, we explore the following research questions.

RQ$_1$. *How do process analysts use process mining to identify improvement opportunities?*

RQ$_2$. *How do process analysts use process mining to select improvement opportunities to address?*

RQ$_3$. *How do process analysts use process mining to communicate their findings?*

To address these research questions, we conducted an exploratory interview study. We interviewed process analysts who use process mining to discover, analyze, and identify improvement opportunities in their daily work. We present

findings on how analysts use process mining when working with business process improvement. More specifically, we describe the strategies analysts employ when using process mining to identify improvement opportunities, compare and assess such opportunities, and communicate their findings. Thus, our findings add to our understanding of process mining solutions use and utility in practice.

The derived insights can be useful for process analysts and researchers in the field of process mining. Process analysts can gain a broader understanding of how to use process mining tools to identify improvement opportunities. Insights on how process analysts use process mining tools to identify improvement opportunities can help researchers develop data-driven discovery of such opportunities, especially for efficiency gains. Finally, our findings can possibly be insightful for developers of process mining tools since they can improve their tools to accommodate process analysts' needs better.

The remainder of this paper is structured as follows. Section 2 presents the background and related work. Then, in Sect. 3, we present the research method, while Sect. 4 presents the results. The findings are discussed in Sect. 5, and finally, we conclude the paper in Sect. 6.

2 Background and Related Work

Process analysts benefit from using process mining to analyze event logs, i.e., data recorded from the process executions [1]. To this end, a set of methodologies have been proposed that aid the implementation of process mining in process improvement initiatives. For instance, Bozkaya et al. [4] and Rojas et al. [25] propose process mining methodologies that address the specific needs of business process analysis in healthcare. The PM^2 framework [30], on the other hand, is industry agnostic and includes planning, extraction, and processing of event log data, mining and analysis of data, and evaluation of results. Other frameworks, such as *Process Diagnostics Method* [4] and the L^* *life-cycle model* [1] support analysts with structuring their work when employing data-driven methods for process discovery and analysis. Thus, the common denominator of such work is that they present an overall methodology for process mining projects. Our work is complementary as we focus on a specific step of such methodologies by exploring how process analysts use process mining to identify and assess improvement opportunities.

Process mining has been applied to real-life event logs for discovery and analysis. Such case studies have been conducted in different domains, such as the customer fulfillment process of a telecommunication company [20], IT management services [31], library information systems [19], agile software development [21], and the cargo release process of a logistic company [16]. Such studies focus on reporting the results obtained by applying process mining and illustrate the value of process mining in industry [7]. In this paper, we provide insight into how such results were obtained by exploring how analysts use process mining to identify improvement opportunities.

Grisold et al. [13] studied organizational and managerial aspects of process mining while Thiede et al. [29] reviewed 144 research papers to understand the

use of process mining by organizations. In a similar vein, in Emamjome et al. [12], 152 case study papers were reviewed to assess the maturity of process mining in practice by using diffusion of process mining and thoroughness of their application as criteria. Syed et al. [28] focus on identifying challenges and enablers of process mining by interviewing stakeholders of one particular organization. Similarly, Klinkmüller et al. [17] reviewed 71 process mining analysis reports to examine the information needed to solve domain-specific problems with process mining tools. These works primarily focus on the organizational perspective for usage of process mining. Our contribution, however, focuses on how process analysts came to the results summarized in the above mentioned case studies and reports. Furthermore, in our work we consider additional aspects besides information needs of process analysts.

3 Empirical Method

To understand how process analysts identify ($\mathbf{RQ}_1$) and select improvement opportunities ($\mathbf{RQ}_2$), and how they communicate their findings to different stakeholders ($\mathbf{RQ}_3$), we conducted an exploratory interview study. This approach is suitable because our aim was to explore a phenomenon – how analysts utilize process mining to improve processes – and gain insights into "how" it takes place from the perspective of the individuals that are involved. We chose semi-structured interviews because they enable a more open conversation between interviewer and interviewees which allows for novel topics to emerge while at the same time providing sufficient structure for a focused conversation on specific topics related to our research focus [11]. In the following, we will elaborate on the specifics of our study setup (Sect. 3.1), data collection, and analysis procedure (Sect. 3.2).

3.1 Study Setup

We recruited a total of seven participants for our study (see Table 1). We selected them across two main dimensions: (1) internal process analysts and consultants, and (2) experience as a process analyst. We chose this differentiation as it can be expected that approaches to identify improvement opportunities vary among individuals familiar with the processes they are tasked to improve (internal process analysts) and those brought in as external experts (consultants) as well as their job experience. Moreover, we also selected our participants from different domains and companies to cover a variety of contexts and use cases. Having conducted six interviews, we noted data saturation, i.e., no new information being provided by additional interviews. We, however, sought and conducted one more interview to ensure we had enough interviews [14]. We conducted individual online interviews with each of the seven selected participants. The interviews lasted between 29 and 46 min each.

Table 1. Study participants

Code	Domain	Project	Study role (experience)
I-01	Electrical engineering	Improving order-to-fulfillment process across multiple countries	Internal process analyst (2 years)
I-02	Insurance	Improving claim-to-resolution process (esp. customer notification)	Internal process analyst (1 year)
I-03	Public services	Improving application-to-approval process for immigration (esp. waiting times)	Internal process analyst (1 year)
I-04	Data science	Improving application-to-approval process (esp. reworks)	Consultant (4 years)
I-05	Auditing	Analyzing claim-to-resolution process at a regional paying agency	Consultant (2 years)
I-06	Process mining	Analyzing standardization and harmonization of processes	Consultant (5 years)
I-07	E-commerce	Improving order-to-cash process (esp. manual tasks)	Internal process analyst (1 year)

3.2 Data Collection and Analysis

Prior to conducting the interviews, we developed an interview guide[4] based on our three main research questions. Thus, the guide included questions related to how interviewees identified process improvement opportunities (e.g., *What was the specific improvement opportunity identified?*, *What were the criteria/measures to identify the improvement opportunities/bottlenecks?*, c.f. $\mathbf{RQ}_1$), and how they decided which opportunity to proceed with (e.g., *How was it decided which one to select?*, *Who made this decision?*, c.f. $\mathbf{RQ}_2$). We also specifically asked each interviewee how they communicated those opportunities they deemed reasonable to implement (e.g., *Who were the results presented to?*, *How did you present your results?*, c.f. $\mathbf{RQ}_3$).

During the interviews we also asked interviewees to provide us with documents, such as frameworks, screenshots of process models, and data tables pertinent to their projects. The interviewees conditioned the interviews on the materials not being made publicly available due to the sensitivity of the contents though. We started each interview by asking the interviewee to think about a recent process improvement initiative they conducted. We proceeded to ask the questions included in the interview guide in the context of this particular project. During the interviews, we did not always stick to the sequence of questions as included in the interview guide, but rather followed the flow of the interview while making sure to cover all aforementioned topics.

[4] Link to the full interview guide and the coding scheme: https://doi.org/10.6084/m9.figshare.19071206.v1.

To analyze the interviews, we first transcribed them by using the transcription tool Otter.ai[5]. After manually reviewing and correcting the transcriptions, we conducted a thematic analysis [5] of interview transcripts and documents. Thus, we first familiarized ourselves with the data and created an initial set codes based on our research questions which included codes such as "*improvement opportunity*" and "*analysis methods*" to discover how the interviewees identified improvement opportunities (**RQ**$_1$). Moreover, we utilized codes such as "*improvement opportunity impact*" to identify how improvement opportunities were selected (**RQ**$_2$) and "*communication media*" to identify how improvement opportunities were reported (**RQ**$_3$). One researcher then applied these codes to the interview transcripts before we discussed the coding results in the research team. The discussion subsequently yielded additional codes such as "*context*", "*process data*", "*communication strategies*". The updated coding scheme was then applied to the transcripts by the same researcher before we again discussed the coding results in the team. We iterated this procedure three times until we did not discover any new codes. The final coding scheme included 14 distinct codes (See footnote 4). During the previously described procedure, we used the documents provided by the participants as additional context information to aid our understanding of the responses.

4 Findings

Here, we present the results of our study. We begin with **RQ**$_1$ on how improvement opportunities are identified, followed by **RQ**$_2$ on how analysts determine which opportunities to address. Finally, we present the results on how process analysts communicate their findings (**RQ**$_3$).

4.1 Identifying Improvement Opportunities

The first research question considers how process analysts use process mining to identify improvement opportunities. Our study shows that analysts take a structured approach when using process mining tools. Analysts identify improvement opportunities by visually analyzing discovered process models, use process mining tools to filter event-logs, and produce process variants for analysis and comparison. In so doing, analysts rely on their combined domain knowledge and process mining skills.

F1. Study participants identify improvement opportunities in a structured manner. For instance, one consultant stated that s/he "*follows the Celonis approach mostly*" (I-04)[6]. An internal analyst (I-01) shared that they follow a high-level framework (doc.[7]) with four steps (select, mine, implement, confirm). Another internal analyst, however, stated that "*I don't use a framework but simply try to find out what each project needs*" (I-02). S/he also confirmed that

[5] https://otter.ai/.
[6] https://www.celonis.com/ultimate-guide.
[7] We use "doc." to mark findings that are based on documents shared.

"*obviously, there is always a part of extracting, cleaning, and analyzing data, interviewing process members, and concluding insights*" (I-02). Similarly, one consultant expressed that "*we don't have a formalized methodology*" (I-05), but, at the same time, "*the way we work is very much like the PM*^{2} *methodology*" (I-05). Thus, process analysts we interviewed follow a structured approach, either iterative or sequential, even if the approach is not explicitly stated.

Table 2. Summary of the findings

#	Finding
RQ$_1$. *How do process analysts use process mining to identify improvement opportunities?* (Sect. 4.1)	
F1	Approaching improvement opportunities identification using structured methods (e.g., process mining frameworks, guidelines)
F2	Dividing the big problem into sub-problems to investigate them separately
F3	Visually analyzing discovered process models, particularly, through filtering and variants analysis and comparison
F4	Finding a compromise between the domain knowledge and process mining outlook of the problem
RQ$_2$. *How do process analysts select improvement opportunities to address?* (Sect. 4.2)	
F5	Assessing the impact of the finding on the process in terms of its location and number of cases and variants involved
F6	Analyzing the dependency on entities outside of the process or the organization
F7	Assessing the financial gain of the finding
F8	Using other tools rather than process mining tools for advanced view into the analyzed data and visualizations
RQ$_3$. *How do process analysts communicate their findings?* (Sect. 4.3)	
F9	Using storytelling to present the finding(s) and selecting visual representations according to the story
F10	Adjusting the communication to the client needs' (i.e., including more technical or business details)
F11	Relieving the findings of process mining details and communicating the results and implications

F2. The analysts interviewed, be it explicitly or implicitly, use an overall framework for applying process mining to identify improvement opportunities. However, identifying improvements requires an in-depth analysis of the processes. To this end, analysts employ different tactics. We observed that analysts decompose the problem into smaller and less complicated parts. For instance, one consultant found "*simplification of the problem*" (I-06) to work. S/he stated that "*dividing the problem into smaller chunks to make it manageable is something which I believe works*" because "*you [...] do not want to start with a very*

complex process, so we start [with thinking] what is the best candidate to start with?" (I-06). Similarly, an internal analyst expressed that "*I think it's better to define one or two improvement areas and just help to improve there*" (I-01).

F3. Study participants also identify improvement opportunities from the discovered process models. As one interviewee confirmed, "*I use like the actual process visualizations to find bottlenecks*" (I-07). More specifically, the analysts interviewed examine the process performance. For instance, an internal analyst focused on waiting times by visually examining the process model to understand "*what kind of steps are involved [...], how long time between steps [...], how many times do the users call*" (I-03). One consultant uses the models to analyze whether "*there are any bottlenecks around the approvals*" (I-05). The analysts studied also combine usage of process mining tools with other analytical tools. For instance, one interviewee conveyed that process maps are useful but "*much more valuable when you have business intelligence capabilities*" (I-03). Similarly, a consultant expressed that for complex things, it is easier to "*move the data out*" and use Python scripts because "*you can do it better with the script*" (I-05). Thus, interviewed process analysts use process models to identify improvement opportunities, such as bottlenecks.

The interviewed analysts filter and compare process models by attributes to identify improvement opportunities. For instance, one interviewee "*showed the differences in process performance for different types of claims*" (I-05). Other internal analysts "*compared it across countries*" (I-01) or considered different years (I-02). What to filter for depends on the business input. According to one consultant, "*before, we used to show the simple variant explorer, but they didn't really work [...] therefore, we are not using the algorithmic grouping of the different variants, but from the business domain, what does make sense to make this grouping*" (I-06). When filtering and comparing, the participants specifically use process mining tools. For instance, one interviewee expressed that "*I mostly used like all of the different types of filterings and, and graphs that you can make in Apromore*" (I-07). Therefore, process analysts seem to discover variants that are compared to identify improvement opportunities. The variants, however, should be defined according to what is sensible from the business perspective.

F4. The visualized process models that analysts use can be misunderstood if one does not understand the data or the business underlying the models. For example, one interviewee said: "*if you don't understand how the data is generated and where the data comes from, you might misinterpret the visualization of the process mining software and, oftentimes, if you don't understand the business process, you might overreact to exceptions that are shown on the process map*" (I-05). Another interviewee, when asked about the same issue, emphasized the importance of domain knowledge. As s/he expressed it, "*I think the most important thing in doing projects like this would be to really understand the process from the people who work with it every day; so like talking to the domain experts, because that's where I think I got the most valuable insights.*" (I-07). The reason is that the process model does not provide all the information needed to identify improvement opportunities.

At the same time, knowledge about process mining is essential for identifying improvement opportunities. The implications of lacking process mining knowledge is that it makes it difficult to evaluate the credibility of the finding as "*okay, you have a finding, but is it a false positive, is it there, do you see it, how do you see it, is it important from the process mining view?*" (I-06). These results suggest that understanding of process mining and the domain are necessary for identifying improvement opportunities. One consultant expressed that they ensure that the process mining team has the necessary domain knowledge. Likewise, one consultant emphasizes the necessity to understand both the data underlying the process visualization and the business processes being analyzed.

Overall, results indicate that process analysts we interviewed follow a structured approach when using process mining to identify improvement opportunities. Such improvement opportunities are identified by manually examining the process models. Analysts look for specific improvement opportunities, such as waiting times, and explore the process models to identify previously unknown connections. Analysts also filter the event log to produce variants that are compared, from which improvement opportunities are detected. Finally, our findings show that both domain knowledge and process mining skills are required to identify relevant and credible improvement opportunities.

4.2 Selecting Improvement Opportunities

Here, we present the results concerning the second research question of how process analysts prioritize improvement opportunities to select the one(s) address. Our results show that process analysts consider the impact the improvement opportunity has on the process, the feasibility of the changes, and the potential savings that can be achieved if the improvement opportunity is addressed.

F5. The interviewees assess the impact the identified improvement opportunities have on the overall process. The impact can be assessed by considering the location of the improvement opportunity in the process. For instance, an internal analyst said that it is vital to "*see in the process where this would actually have an impact on*" (I-02). The impact can also be considered by considering if the improvement opportunity "*involves a large population of the process*" (I-06). For instance, in one case involving variants, a consultant expressed that the impact is considered "*with the total number of variance that we see, what is the ratio between the total number of variances and ratio of the process population*" (I-06). Thus, studied process analysts assess improvement opportunities by their impact on the business process.

F6. Another parameter used to determine which improvement opportunities to address is the dependency of the required changes. The dependency is assessed by considering whether the changes require involving external processes or other departments. As one consultant, when discussing a particular improvement opportunity, put it, "*but that's external to the process, so you can't do anything with that.*" (I-05). Another aspect that impacts the dependency is the input of process experts, subject-matter experts, and end-users. For example, an internal analyst said that "*I presented to them everything that I found based on*

the data, [...] and then they gave me feedback about what they would implement and would not implement and why." (I-07).

F7. The main measure used to assess and prioritize improvement opportunities is its financial gain. In the end, "*it's always about the money*" (I-01). The savings that can be realized must be estimated. As one internal analyst put it, "*we build some sort of a business case on how much we can save*" (I-01). The improvements that produce the greatest gains are prioritized "*based on where we can gain the most, and where the biggest problems are*" (I-01). If the financial gain is not sufficient, the improvement opportunity is rejected. One internal analyst stated that "*90% of them are rejected and we [...] want to focus on the ones that will bring us a lot of savings. For example, [...] working on 100 orders is not really saving, it's like someone spends five minutes on this, we're not going to spend all our efforts and time to tackle this problem*" (I-01).

F8. A standard view among the participants was that additional tools, such as Python or Tableau, are needed for visualization. For instance, one consultant shared that s/he uses both Python and Tableau (doc.) because the visualization of process mining software provides "*general statistics, which is really, really, really cool, but oftentimes, if you want to go into more details, you need something more, and that is why I use Tableau*" (I-05). The same reason was given by an analyst expressing that "*[I] use Disco for process mining and write Python scripts when [I] need additional visualizations*" (I-02). Another analyst applied the same tactics but with Excel (doc.) For instance, regarding the process mining tool limitation, "*I also used just Excel for kind of correlation visualization and percentage analysis, because that's not what you can do [with process mining tool].*" (I-07).

In summary, these results show that improvement opportunities are assessed by their impact on the process and their ratio of other cases. Besides, the feasibility of the required changes, input from process and subject-matter experts are also considered. Process analysts also require visualization and advanced data analysis which is not provided by existing process mining tools. Therefore, analysts rely on additional tools, such as Python and Tableau, to analyze and visualize process data.

4.3 Communicating Results

The final research question concerns how process analysts use process mining to communicate their findings. Interviewed process analysts communicate their findings by developing a story that is supported by data and visualizations. Furthermore, analysts simplify the results to suit the audience.

F9. The interviewed process analysts communicate their findings by framing them as a story. In the words of an internal analyst, communicating the findings is "*like storytelling for managers with process mining*" (I-02). For instance, one consultant explained that "*when presenting something to management, you don't have time, and they don't have the attention span to listen to the whole thing and to understand all the details*" (I-05). To this end, to make the findings digestible and relatable, "*you take that piece of information or data and try*

to put it in a simplified context that works as a narrative and easy enough to understand" (I-05). Given that all the information cannot be shared, a story facilitates putting "*away your technical geeky part and think with a business mind*" (I-05) to consider if "*from a business point of view, this one might have an impact, this one makes sense, and this is strong enough to make a change*" (I-05).

Similarly, a story guides the analysts in what visualizations to use. For instance, one interviewee said that "*when it comes to additional visualizations for reporting, I use outputs from Disco thinking what screenshots exactly would fit what I want to tell*" (I-02). The types of visualizations used vary (doc.), but often, they are "*basically just a screenshot from the system*" (I-01). However, analysts also use process mining to communicate their findings. One internal analyst reported that "*typically, I show them [end-users] things interactively while explaining in parallel*" (I-03).

F10. The communication of findings should be adjusted to the client. For instance, one consultant said that "*different clients have different modes of communication. Some clients require very formal approaches*" (I-04). Regardless of audiences' preferences, process analysts modify the contents by simplifying and adding clarifications. For instance, one consultant creates new visualizations when communicating the findings. "*I tend to use overly complex visuals because I understand them because I created them. But since I'm not sure anybody else would understand it, [...] then I create another one that is very specifically targeted to communicating a message*" (I-05). The same interviewee expressed that "*the ideal process mining software would allow you to be focused on the analytic visuals, but also would let you make or parameterize simplified visuals for communications*" (I-05).

F11. The importance of simplifying is because if the target audience "*would see a process and a very complex process, but then the next question for them would be, So, what shall I do with this?*" (I-06). To simplify, an internal analyst frequently changes the names of the activities when communicating the findings "*when I need to report to some managers who do not understand the names of the activities*" (I-02). The layout of the process diagrams can also matter. The internal analyst who compared the process model for two different years noted that "*the process maps for two different years had different layouts which caused the management to think that one step disappeared, whereas it was just arranged differently*" (I-02).

In summary, analysts we interviewed frame their findings as a story and select data and visualizations according to the storyline. In selecting visualizations, analysts use screenshots and use the process mining tools interactively. Furthermore, the findings' contents are often simplified, and, if needed, custom visualizations are used.

5 Discussion

Our findings provide indications on how analysts identify improvement opportunities with process mining (**RQ**$_1$), what aspects influence the assessment of such opportunities (**RQ**$_2$), and finally, how the findings are communicated (**RQ**$_3$).

With regards to **RQ**$_1$, our findings suggest that process analysts take a structured approach when using process mining for improving processes. This is according to the previous results that confirm the need for a structured approach to process mining projects [1,4,23,30]. Process analysts seem to develop methods based on their experiences. This might be due to standard methodologies describing general activities rather than defining more detailed guidelines and specific steps for process analysts to follow [2]. However, we note that such methods are similar to standards ones, such as the PM^2 [30].

Our findings also suggest that process analysts use process mining to find specific weaknesses, such as waiting times, in business processes by, for instance, filtering the event-logs along various dimensions. Also, analysts identify improvement opportunities by exploring the processes with process mining. When exploring, analysts use filtering and variant analysis to find connections between various process parameters that suggest potential improvement opportunities. These findings are aligned with experiences reported in process mining case studies, such as [16,20,31]. However, analysts do not seem to use thematic analysis templates such as those proposed in Djurica et al. [9]. This might be due to such templates not being commonly integrated with process mining tools or that analysts are unaware of them. Our findings on the tactics of process analysts to decompose process issues and apply business-driven rationale for defining variants provide insights not commonly discussed in process mining studies.

Our findings indicate that process analysts use additional tools besides process mining tools. Process mining tools are predominantly used for the discovery of process models and filtering. However, such tools seem to lack the functionalities that process analysts need for visualization. Therefore, process analysts use other tools for visualization techniques not specific to process mining tools. In this regard, our finding is consistent with that of Klinkmüller et al. [17]. In contrast, our findings provide insights as to the reasons why process analysts use other tools.

As to **RQ**$_2$, expectedly, process analysts use the relative financial gain as the main criterion for assessing which improvement opportunities to address. However, it is interesting to note that process analysts consider process impact, the feasibility of implementation, and input from other stakeholders, such as process experts, subject-matter experts, and end-users, when prioritizing and determining which opportunities to address. These findings, besides the financial gain as primary criterion, have not previously been extensively discussed.

Furthermore, we note that dependency on entities outside of the process or the organization is also considered. This finding is aligned with that of Thiede et al. [29] who found that process mining is mainly concerned with a single process in a single organization. Process managers find it challenging to select which process to analyze [13]. Restrictions on access and use of relevant and

required data [13] might constrain process selection to a single process whereas the analysis could provide more value if cross-system and cross-organizational processes are analyzed with process mining. Therefore, we found that expanding the scope beyond the process being analyzed with process mining is relevant, but process mining tools do not support it sufficiently.

As to (**RQ**$_3$), our findings indicate that analysts frame their findings as a narrative when communicating their results. Such narratives determine what data and aspects to emphasize. Furthermore, process analysts simplify the analysis and the visualizations when presenting them. Analysts could use process patterns [3] and anti-patterns [18] to facilitate the communication of the improvement opportunities. However, analysts do not seem to use them. Similarly to redesign patterns [9] discussed earlier, this might be due to analysts not being aware of them or that they are not integrated as visualization aids in the process mining tools and, therefore, not feasible to use.

Finally, process analysts use process mining tools to communicate their findings, either by using such tools interactively or by taking screenshots. Our findings shed additional insights on the process behind the results presented in case studies of process mining, such as [16,19,21,31]. However, such studies do not use a story to select and frame the data when presenting their results.

5.1 Implications

Our research has implications for process analysts and developers of process mining tools. More specifically, our findings can be useful for practitioners by providing them with insights on how process analysts work with process mining when engaged in business process improvement initiatives. In addition, providers of process mining solutions can improve their solutions by considering and incorporating visualizations that better cater to the needs of practitioners.

Out findings can be helpful for practitioners. Practitioners manually analyze the output of process mining solutions and, therefore, improvement opportunities can remain undetected. Analysts might overlook an opportunity, or detection might require analysis that is not feasible or possible with existing process mining tools. As a first step, a set of process mining analysis templates can be developed that help analysts to identify common improvement opportunities. While there are a few available, such as discovering rework[8], there are no validated collection of such templates. However, as the next step, insights into how analysts use process mining tools to identify improvement opportunities can help researchers develop algorithms for data-driven discovery of improvement opportunities.

Our findings also have implications for developers of process mining tools. Understanding how analysts use process mining tools to analyze and identify improvement opportunities can help developers to develop process mining tools to serve their end-users better. For instance, such tools can be enhanced to use visualization and patterns to identify opportunities, facilitate analysis of

[8] https://fluxicon.com/blog/2017/03/how-to-identify-rework-in-your-process/.

dependencies of a process with other processes, improve visualizations for communication purposes, and incorporate support for financial implications of the processes. Frameworks that aid developers with choosing visualization methods for process mining outputs have been proposed [26]. However, such frameworks focus on descriptive process mining and do not extend beyond process discovery and implicit analysis. Our findings provide insight into what should be considered when developing visualizations for process improvement opportunities.

5.2 Limitations

Our study aimed to explore how analysts use process mining when working with process improvements. These aspects have received limited attention in research so far. It is, thus, appropriate to conduct an exploratory interview study for the given research context. However, there are inherent limitations related to such study designs. We studied seven process analysts who worked on a specific process improvement project within a specific company that operates within a specific domain and utilized specific process mining tools. While we made theoretically motivated selections and selected participants across different domains working in different companies, it can be expected that other study participants working on various process improvement initiatives in different companies, utilizing different process mining, might yield different results.

Moreover, our study population only contained one senior analyst. This can be expected, though, since process analyst commonly is a junior position. We also did not conduct all interviews in the same way, which could inhibit comparability. Our interest was on discovery rather than comparison or prioritization. We also further mitigated this threat by ensuring that we would cover the same topics related to our research questions in all interviews. Another limitation may be related to the number of interview participants. We noted data saturation [14] after six interviews but conducted one more to ensure we had not missed anything. However, we acknowledge this may still remain a limitation to how generalizable our findings might be.

Additionally, a single researcher's coding of the interview transcripts might induce interpreter bias. We attempted to mitigate this bias by ensuring that we followed an established analysis procedure and collaboratively discussing findings at multiple points during the analysis. We also abstain from making causal claims and prioritizing specific findings or interpretations. Instead, we provide a detailed description of how different participants utilized process mining to identify and select improvement opportunities and reported their findings.

6 Conclusion

This paper presented findings from an exploratory interview study on how analysts use process mining to improve business processes. The study specifically aimed at exploring how process analysts use process mining to discover process improvement opportunities, select which ones to address, and communicate

their findings. We conducted seven interviews with process mining practitioners, namely internal process analysts and consultants.

Our findings provided tentative insights on the usage of specific methodologies in process improvement projects and the application of process mining. To this end, process analysts follow standardized methods such as PM^2 but also develop their own methods catered to specific organizational needs. When implementing the projects, they do not use process mining tools in isolation but combine them with other analytical tools, such as Tableau, for deeper insight into data. Additionally, we discuss the criteria that process analysts use when prioritizing improvement opportunities, among which are financial gain and dependency on external entities. Our findings also provide indications on how process analysts communicate their findings from process improvement projects, with storytelling being a common method.

Our findings also indicate the importance of visualization of data and process models to identify improvement opportunities. Therefore, for future work, we aim at exploring how visualization can be used to facilitate the identification of improvement opportunities.

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