Expectations vs. Experiences – Process Mining in Small and Medium Sized Manufacturing Companies*

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Abstract. While literature emphasizes the importance of process mining for pushing digital transformation in manufacturing, it remains unclear how process mining can be actually implemented and used by domain experts, especially in small and medium sized manufacturing companies (SMMC). This paper provides the findings of a focus group study, i.e., expectations on and experiences with the introduction of process mining in SMMC, including employees in different positions, e.g., process supervisors and shopfloor workers, and exposure to process mining. Transparency, for example, is an expected benefit for managers, facilitating the collaboration with business partners, error prevention, and legal protection. Shopfloor workers, in turn, perceive transparency as possible threat. The implementation of two process mining scenarios at one of the SMMC led to reduced documentation effort which helped to win over shopfloor workers. Altogether, the findings of this study can help to address concerns and challenges (e.g., with the infrastructure and data collection) early when introducing process mining at SMMC.

Keywords: Process Mining · Manufacturing · Small and Medium Size Companies · Focus Group Research

1 Introduction

Gartner reports a steep increase in process mining use cases for digital transformation and process automation [8]. A domain that poses particularly high demands on process transparency and digital transformation is manufacturing: it combines the physical world (e.g., sensors, machines), human work, and manufacturing systems. [16] presents best practice use cases and [5] emphasizes the

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importance of process mining due to the data that is available in a manufacturing company. However, studies on process mining expectations and experiences in Small and Medium Sized Manufacturing Companies (SMMC), are missing although SMMC account for 55.4% of manufacturing companies in the EU[3] and for 44.4% of the employees in manufacturing in the US[4]. Moreover, these expectations and experiences have not been analyzed from the viewpoint of different organizational positions so far. It can be expected that due to the differences in daily work life as described below,expectations might vary which should be considered for a smooth introduction of process mining:

(1) *Shopfloor workers* tend to perform their work in a process-oriented way due to the structure of manufacturing processes, since a certain set of tasks has to be applied in a logical order. Even though most machines nowadays have their own logging mechanism, there is often no software orchestrating resources as well as coordinating the cooperation with other departments.
(2) *Supervising operatives* usually can observe specific steps in a process instance. If a workpiece or process subject is faulty due to an error, it is often unclear how and where in a process an error started occurring. Process mining can be vital for optimizing processes and detecting erroneous behavior.
(3) For employees in *managing positions*, transparency is especially relevant. Transparency is a crucial aspect for companies nowadays, for legal protection as well as for cooperation with other companies. Process mining can increase the transparency by providing knowledge about business processes and their execution.

The following research questions aim at analyzing expectations on and experiences with process mining in SMMC from different viewpoints and with different exposure to process mining (before/after the introduction and application of process mining):

RQ1 What benefits and drawbacks are expected by SMMC when introducing process mining?
RQ2 What benefits and drawbacks are perceived by SMMC after the introduction of process mining?
RQ3 How can the implementation of process mining at SMMC be designed?

This work tackles *RQ1* – *RQ3* based on a focus group study following the guidelines stated in [10]. Focus groups have proven themselves as adequate means to assess the impact of process mining in practice [7]. The specific study design for addressing *RQ1* – *RQ3* is developed along a double layer approach enabling the distinction of the organizational position of participants and their exposure to process mining. The double layer approach is realized by two rounds of interviews with employees of two manufacturing companies covering organizational

[3] `https://ec.europa.eu/eurostat/statistics-explained/pdfscache/10086.pdf`
[4] `https://www.sba.gov/sites/default/files/advocacy/2018-Small-Business-Profiles-US.pdf`

positions (1), (2), and (3). Moreover, in one company, process mining has already been introduced and the other is planning the introduction of process mining in the near future. Two real-world cases for process mining in manufacturing, i.e., electroplating and electronics assembly, are described in detail.

The findings of this study show that the expectations involve increased transparency which is crucial for collaborations with business partners. In addition, it is expected that process mining can help to detect deviations in process executions at runtime. Main concerns regard employees feeling observed by the increased transparency and reluctance of them to share tacit knowledge. The introduction of process mining confirms that the expected benefits indeed occur. Moreover, the decreased documentation effort for employees, due to process mining, outweighs the fear of surveillance of employees.

The paper is structured as follows. Section 2 introduces fundamental terminology and discusses related work. Section 3 explains the detailed structure of the focus group study and the participants. Section 4 introduces the real-world scenarios for process mining application in manufacturing. Section 5 contains a summarized overview of the results of the focus group interviews. The findings that can be deducted from the interviews are discussed in Sec. 6 where also future implications based on these findings are discussed and the research question answered. The paper is concluded in Sec. 7

2 Background and Related Work

Process mining aims at three analysis tasks: (i) process discovery detects a process model from a process execution log [2,3]. Several discovery algorithm exist, e.g., [11,21]. (ii) conformance checking compares a process execution log to a process model resulting in a fitness value [1]. (iii) process enhancement uses a process model and a process execution log to detect bottlenecks and helps improving the efficiency of a process.

Tasks (i) – (iii) use process execution logs (see e.g., [2,3]) as input. A process execution log consists of a set of traces where each trace stores the events that occurred when executing a process instance. Process execution logs reflect already finished process instances. If process mining techniques are applied on process execution logs, they are applied in an offline manner, i.e., ex post. If process mining is applied during runtime, process event streams are used instead of process execution logs [22,4,19,14]. An event stream consists of events of multiple process instances and is created and processed at the point in time an event is executed, with the typical stream features, i.e., it can only be processed once and in theory there might be an unlimited amount of events in a stream.

The advantage of online process mining is that domain experts can observe the results, as the process instances are being executed. This enables them to counteract undesired behaviour that could lead to errors, i.e., stopping a process instance that is not matching the behavior of the process model or discovering that the mined process model is not reflecting the planned logic at all. Plenty of tools and libraries are available to perform online and offline process mining

on suitable data, i.e., the open source framework ProM [20] and PM4Py [3]. [13] provides an overview of process mining techniques, open source tools, and commercial tools in the context of the Business Process Intelligence Challenge.

But how are process mining techniques actually applied in practice? One aspect is the application of tools and systems. Here, [12] argues that commercial tools are often not user-friendly. Another aspect refers to challenges and solutions when introducing process mining independently of the tool. [7] conducted a focus group study looking at the challenges of introducing process mining from a managerial perspective. The usage of process mining in organizations and how to start an enterprise with process mining in mind, is explained in [16]. Here, several best practices are presented from projects in different organizations, like Siemens, BMW and Uber. A case study of how process mining can be used in the manufacturing domain is also represented in [9], where the usage of process mining is discussed for every category related to the Six Sigma quality management philosophy.

The study at hand aims at digging deeper into expectations and experiences with process mining in the manufacturing domain, especially for SMMC, considering different viewpoints and actual results of process mining projects.

3 Overview on Methodology and Study Design

This study employs focus groups [10] to assess the expectations on and experiences with process mining in SMMC.

The focus groups are organized according to the double-layer design depicted in Fig. 1. The first layer distinguishes the focus group participants by their organizational positions, i.e., shopfloor worker, supervising operative, and manager. This distinction aims to identify the impact of process mining from different work perspectives. The second layer distinguishes the participants by exposure to process mining in their current company, i.e., if process mining has already been used in the company or not. Doing so aims at comparing the general expectations on process mining to its actual results.

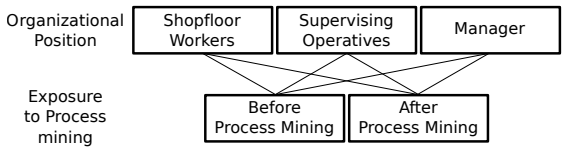

Fig. 1. Double layer focus group study. All participants are grouped along both layers.

Two rounds of focus group interviews were conducted. The first one consisted of three people who have not been using process mining in their work at the moment, but are planning to implement it in the near future. The second group consisted of four people, who are already using process mining, and plan to increase the usage of process mining.

As depicted in Fig. 1, participants of the focus group interviews can be distinguished along two layers.

The first layer focuses on the organizational position of a participant. In order to identify a set of participants for the focus group, we identified a representative set of roles and their responsibilities based on [6]. As both companies operate in a lean teamworking environment but are SMEs and thus not necessarily differentiate roles as much as big companies, we coordinated with them to narrow the set of roles down to a feasible number, that was then basis for organizing the actual focus group. (1) reflects shopfloor workers who execute the tasks on the shopfloor. This task execution is then logged for applying process mining. Hence, the shopfloor workers can be seen as directly confronted with process mining and its results in their work life. (2) reflects the supervising operatives of a company who are monitoring the shopfloor. Supervising operatives are interested in using process mining to discover rarely executed paths in a business process, use conformance checking to detect faulty process instances and tasks that caused a failure. (3) reflects the manager of a department or company. Process mining can be used to evaluate the general performance.

The second layer of this focus group study emphasizes the exposure of process mining in the company. The participants are therefore split into two groups. (1) of the second layer, reflects employees in a company which has not used process mining yet. The second group, (2) consists of employees who are using process mining already. The associated process scenarios are introduced in Sec. 4.

4 Applied Process Mining Scenario

The study design outlined in Sec. 3 demands that selected participants of the focus group have already been exposed to process mining which is an important part of the interviews and the findings. This section will thus introduce the scenarios in which participants of the focus group (Shopfloor Workers & Supervising Operatives) experienced the application of process mining.

4.1 Electroplating

Company `E` produces parts which have to be surface-treated. This is done by submerging these parts in a chemical bath, giving them certain desired properties. After the bath is used for a certain amount of parts, or if the bath has been inactive for a certain time, it has to be refilled. For refilling, certain (dangerous) chemicals have to be combined. Before introducing a BPMN process-based orchestration solution to support the process, workers were following guidelines, taking notes, and manually filling out reports. In cases where these guidelines were not followed, accidents have occurred. Avoiding these kinds of accidents was one of the main reasons to introduce an orchestration solution.

After introducing a process-based solution, the process was formalized as depicted in Fig. 2. The solution consists of two parts (CPEE [15] BPMN notation): Fig. 2 (a) depicts a control process that determines based on sensors and human

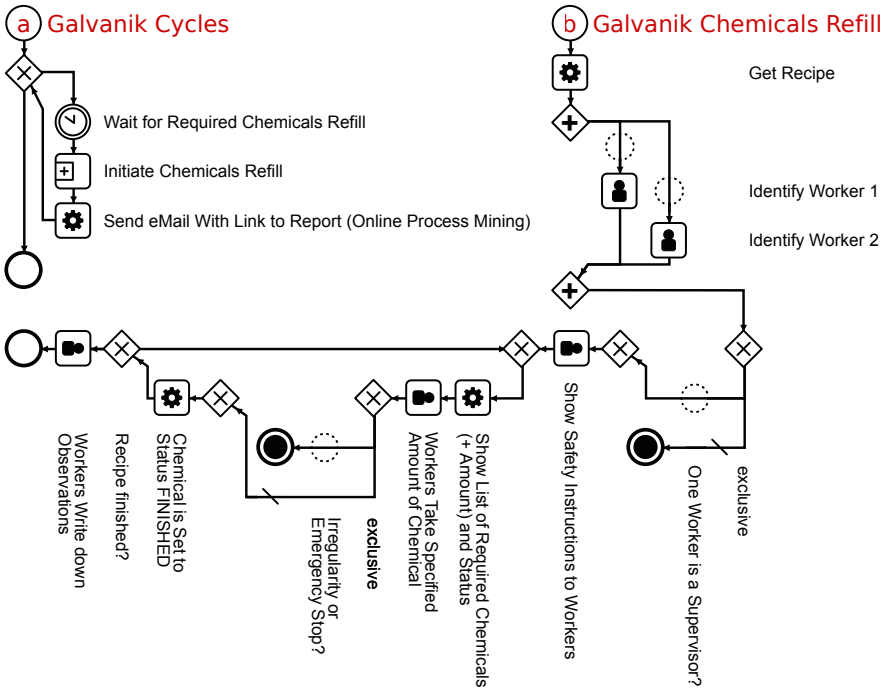

Fig. 2. Electroplating – A bath for surface treatment of parts has to be refilled after use or time

input, when to start a refilling cycle. Figure 2 (b) depicts the actual refill process, as carried out by two human workers. Figure 2 (b) starts with selecting a refill recipe. This can be either based on input from sensors in the bath or through human intervention from a supervising operative.

The recipe consists of a list of chemicals, and the required amount. Afterwards, the system waits for two workers to identify themselves through their NFC badges at the entrance of the chemicals storage locker. Only after their identity and role is established (one worker and one supervising operative are required), the locker can be opened. A screen shows which amount of which chemical has to be taken and added to the bath (in no particular order). Each chemical is in a container that is mounted on a digital weighting scale. Thus when the wrong amount of the chemical is taken, an emergency stop can be triggered. It is also possible to automatically track which chemicals have been used, as well as their exact amount. The workers are encouraged to write down their observations at a computer terminal after they are done (and the protective gear is removed).

Online process mining techniques, including mining for data elements, sensor data and time deviations, have been utilized to generate detailed reports

about each instantiation of Fig. 2 (b). These reports are sent to all supervising operatives at the end of each cycle depicted in Figure 2 (a).

4.2 Electronics Assembly

Company E manually assembles products which consist of different parts (> 100, including slight part variations). This leads to over $64,000$ possible variations that can be ordered by customers. Typical order sizes range from 2 to 500. The assembly involves soldering as well as intricate mechanical manipulation of parts that are less than 2 millimeters in size. This high variance, paired with the required intricate mechanical manipulation is a major hurdle for automatic assembly, thus the assembly is carried out by humans. The human workers have different skill levels. While some have the knowledge to assemble all variants from the back of their head, others need guidance which is provided by the experienced workers as well as through extensive technical documentation.

The problem is that many details involve tacit knowledge, i.e., knowledge that just exists in the minds of the workers. For quality assurance and product improvement it is not easy to determine which particular step during the assembly took how long, and which steps were most error prone.

In order to solve this problem, the assembly has been split into a number of sequential work packages, and for each work package a graphical worker assistance system system has been designed. All logic for selecting individual steps and showing them on screen is implemented as a BPMN process-based solution. The worker assistance system automatically shows the correct set of steps for the work-piece in front of the worker (no variants have to be remembered), and also assumes a standard order of putting work-pieces together. Each step has to be acknowledged with a foot pedal. When a problem occurs, a worker can leave a (spoken, speech-to-text) note, and dismiss the work-piece for later fixing.

This setup forms a good basis for (online) process mining. It is possible to extract detailed information about durations and error rates, paired with information about the particular work-piece variation, used parts, and steps. Online process mining techniques are used to generate early warnings for supervising operators. Ex-post process mining is utilized for continuous process improvement. Though company E just started utilizing the system, early results have been deemed promising by workers, supervising operators, and management.

5 Results of Focus Group Interviews

The double layer design of the focus group study is depicted in Fig. 1 and explained in Sec. 3. The focus group features two interviews with employees from manufacturing companies CDP and E.

Manufacturing company CDP: The first focus group contained participants of two management levels. Three participants were interviewed, i.e., one supervising operative, and two general managers/CEOs. None of them was using process mining in their department at the time of the interview.

Manufacturing company E: The second focus group contained participants of three management levels. Company E is in the metal-processing domain and employs around 750 people. Four participants have been interviewed, i.e., two supervising operatives, a general manager and one shopfloor worker.

After an introduction into process mining, all participants revealed a good understanding of the basic principles of process mining and could identify scenarios in their company, where process models are already in place, i.e., in the electroplating department (cf. Sec. 4.1).

Table 1 provides a summary of the profile of the participants to identify theirs answers. In the following, the interview results are presented for each question.

Table 1. Focus Group Participants Profile

Coding Participants	Company	Position	Experience in Company	Working with Process Mining
EA	E	Supervising Operative	>10 years	yes
EB	E	Supervising Operative	2-4 years	yes
EC	E	General Manager	>10 years	yes
ED	E	Shopfloor Worker	>10 years	yes
CA	CDP	Supervising Operative	>3 years	no
CB	CDP	General Manager	>2 years	no
CC	CDP	General Manager	>4 years	no

What benefits do you see in a process-oriented view of your field?

ED thinks that one's workload is better structured using a process-oriented view, which increases the cooperation quality with other departments. The operative CA, sees benefits of process mining with respect to the transparency of their department and their company. Knowledge, in particular, domain specific knowledge is lost if an employee leaves, is a concern mentioned by CA. Workflows here are not explicitly available as formal models, but workers loosely follow learned rules/guidelines, hence it is difficult to detect the source of an error. Conformance checking and process model discovery are regarded as useful techniques to ease these problems. These benefits are confirmed by the operatives EA and EB. The correct execution of a process instance, supervised by process mining, allows them to detect and react to errors as soon as they happen. Moreover, the process models enable a good visual representation of the currently active tasks. EB mentions that, *"A huge advantage of a process-oriented view is the improved communication between employees from all levels"*.

The managers, CB and CC, share concerns regarding the usability of process mining in the daily routine of employees. The discovery of process models is seen as an important feature of process mining as it increases transparency, which is often required for cooperations with other companies. The correct process execution is crucial as well, to discover and fix problems. EC confirms the previously outlined benefits. In addition, the application of process enhancement is envisioned in the near future, through implementing lean management techniques

and optimizing resource sharing between multiple departments.

How are processes and tasks executed and logged at the moment?

ED states, that their department uses work instructions as a basis for processes, obtained by interviewing workers. It was mentioned that this is useful for new employees, but yields some uncertainties (e.g., for rarely produced parts). CA explains that most of the activities are still logged manually in a rudimentary way without much information on the input / output of each task. The detection of faulty behavior in the process execution is crucial, but hard to track without a rich documentation. EA mentions, that unlike the electroplating unit, in his unit everything is currently only logged in an ERP-system. However, these event are only available at a high level and only for certain tasks, e.g., only measurements are logged, but not the production itself. These logs are used for making operational decisions, such as determining the delivery date. EA is aware that this leads to resource waste, as parallel processes are not properly synchronized, and departments sometimes have to wait on other departments, because they decided on a sub-optimal production order. EA also claims, that the work instructions mentioned by shopfloor workers, are often not followed, but instead slight variations learned from colleagues are used. CB emphasizes again, that identifying errors and increasing the efficiency is very important. Therefore, processes have been modeled showing the interaction between humans. These interactions are currently logged in an ERP system. Process mining techniques such as conformance checking or using a system to enact the correct tasks at the right time have not been used. EC is aware of the benefits of process mining in the implemented scenarios. Additionally EC mentioned the wish to implement process mining at the managerial level, i.e., mine and analyze management processes.

How is the correct execution of a process model currently ensured?

Process models are used and tasks are logged with a process execution engine in the application scenario of the electroplating unit as mentioned by ED. Currently active tasks are shown on a screen and are executed by interacting with the screen. CA, CB, and CC state that, as no process models are used, their correct execution is not ensured. EA explains that, correctness for the scenarios is enforced by a process engine, but for many other scenarios, the status quo has not changed. EB says, that additional process mining techniques to automatically notice errors is desirable, as currently root-cause analysis for errors is mostly done manually. EC is aware of the benefits of process mining in the implemented scenarios as decisions regarding high-level process changes become easier, and controlling is improved. EC again states that processes at managerial level should be formalized as well.

Which advantages do you see for your company with the support of process mining?

ED sees a reduced documentation effort due to automatic documentation. The instructions are well presented and help following the process model. CA emphasizes the importance of process enhancement as an important factor in the company, but is also keen on improving the efficiency using process mining techniques in general. EA sees a lot of potential, especially for protection against insurance claims if accidents happen or if products do not adhere to the quality standards. EB mentions that with increased process standardization they would be able to take on more risky projects. EA mentions an accident that happened in a sub-department where the cause could not be determined. To avoid such accidents in the future, it is essential to better structure the workflow, making it more transparent, provide support for the employees taking part in critical processes and log interactions with dangerous chemicals. CC sees advantages in understanding of processes for different positions in the organizational hierarchy. CB also thinks that processes can be communicated better between companies from different domains for a more efficient cooperation. With the help of process mining, especially process discovery and conformance checking, the perspectives of the shopfloor level and the management level should be more aligned. In the company, workflows rarely show deviations and more often follow a common path, which should allow for understandable process models. CC mentions explicitly that *"While a performance evaluation of a process can be done every three months and does not have to be online, a deviation of a process instances should be reported immediately"*. EC added, that there are additional benefits for planning and analysis that could be obtained by introducing process mining.

Which advantages do you see for your specific department with the support of process mining?

ED sees a big advantage, in the training of new employees with the use of process models and process mining. Process models provide a good visual representation of the workflow and allow for a better communication between departments. Online process mining can give immediate feedback about the current state of produced parts. CA points out the importance of identifying errors and the increased efficiency when communicating with other departments based on data produced by process mining. Both operatives, **EA** and **EB**, think that process transparency is increased due to the use of process models and a process execution engine. They mention automatic reports after each crucial step executed by shopfloor workers, which help to ensure the conformance of a process instance (regarding many aspects: process structure, timing, resource deviations, data deviations). **CA** emphasizes that not only the production should benefit from process mining techniques, but tasks involving only humans as well, such as creating reports, delivering a product, and communication between departments. EC again emphasize that data obtained through process mining (e.g., duration & resource utilization for a multitude of product variations) are a huge benefit for planning and process optimization.

What problems do you anticipate for the introduction of process mining in your department?

ED sees the benefits of process mining in one's department, but fears that long-term employees still might not see the purpose of process mining in other departments, because they are often not interested in changing their daily routine. However, **ED** states that if the benefits, i.e., less documentation effort, are clear to the employees, they can be convinced. CA voices concerns about the acceptance by the workers, since they tend to use their acquired knowledge to secure their position in the company. CA also fears high costs for heterogeneous workflows, since the discovery of the process model and its variants could imply a huge effort. The advantages of process mining are clear in CA's opinion. **EA** fears that the employees could feel observed. Hence, **EA** thinks it is important to encourage strong involvement of employees when implementing future scenarios. **CC** echos the concerns about employee acceptance. The increased process transparency is viewed as critical, as it paves the road towards cooperations with future customers and partners. CB voiced concerns, that the increased logging and data availability makes data leaks possible, which would harm the company. **EC** thinks that employee acceptance is a challenge, but in hindsight was easier to achieve than expected. **EC** thinks that the introduction for the whole company is too complex and that they will aim for implementing process mining in many small projects (as they want to focus on techniques that require heavy use of domain knowledge –analysis of process data, durations and resource usage). Lastly, *EC* raises the concern that the current IT infrastructure (networking and computational power– more sensors produce more data requires more analysis capabilities) and human resources are not sufficient. Currently, process mining has been successfully introduced in one department.

6 Discussion and Implications for Research and Practice

Based on the results of the focus group interviews as summarized in Sec. 5, we deduce the following findings. The findings can be categorized as follows:

- Requirements before process mining can be introduced.
- Expected results when introducing process mining.
- Actual improvements after process mining has been introduced.

The remainder of this section discusses these three categories in detail and answers the research questions set out in Sec. 1.

6.1 Requirements

The settings in both companies CDP and E distinguish themselves by the granularity of the logged tasks. The first focus group from CDP does not use any of the three fields of process mining at the moment, but is already working with the support of a process execution engine, which enables the creation of an event

stream and the automatic documentation of each task in a process. In company E, by contrast, not every task is logged, but only certain checkpoints, i.e., a finished piece. This leads to inaccurate process execution logs, since it is not clear, how and when the different tasks have been executed. Company E is using a process execution engine only in a sub-department. In other departments of company E different approaches have been tried, i.e., a manually created handbook of business processes for new employees. Unfortunately, this handbook is rarely used and instead knowledge is transferred from senior employees to newer ones. This leads to undocumented steps, which renders retrieving fine granular results and therefore process mining on a more granular basis impossible.

The focus group interviews showed, that even though companies are putting effort in creating process models through intensive interviews with employees and are making these process models available, the documentation of tasks is often too time consuming. However, the introduction of process mining supported by a process execution engine showed, that employees are willing to log their tasks if enough support is available, like a monitor showing the current active task and an automated documentation. The supervising operatives and managers are benefiting from the generated reports about conformance of a process instance and general behavior through process mining.

6.2 Expected Results

Most of the participants share similar experiences concerning the process of creating process models i.e., through interviews, since employees often follow a process from tacit knowledge. Since it is important to be as transparent as possible for potential business partners as per the statements of the focus group participants, a better representation of the actual processes is desired. Another important factor concerns correct process execution as this increases transparency. The participants also emphasize the moment of time when a deviating process instance is detected. While the evaluation of a whole department can be calculated every few months, a process instance with a deviating conformance should be detected as early as possible. To check the conformance during execution, an event stream is required to apply process mining.

For the implementation, the participants raised concerns about the introduction of process mining in their departments. Employees could feel observed, since their daily routine could be analyzed from the process execution logs. Another problem is, that employees sometimes tend to gather knowledge and not share it, making themselves harder to be replaced. The participants agreed, that the employees should be involved in the process of introducing process mining. It was also mentioned that as soon as the benefits of the approach became very clear, acceptance was very high.

In addition, it was mentioned, that the IT infrastructure could be an issue for implementing process mining.

The findings discussed above summarize the expected benefits and drawbacks of process mining in companies and hence contribute to answer **RQ1**.

6.3 Improvements

The introduction of process mining in a department of company `E` results in the following improvements. The process of obliging two employees to perform several tasks, where one of them has to have a specific role, can be accurately logged with the support of a process execution engine. Conformance checking, taking the data perspective into account, can reveal deviations, if the criteria of the correct amount or the correct roles is not fulfilled. Another important aspect is the temporal perspective. Conformance checking allows to detect temporal deviations in the process, e.g., an extremely short duration for putting the protective gear on, leading to the assumption that the gear is not worn correctly.

When a deviation is detected at runtime, it is possible to provide the company with the information for which process instance the deviation occurred. With this information, it can be tried to explain the reason for this deviation through the information stored for a process instance by the process mining framework.

Based on the findings, **RQ2** concerning the actual benefits and drawbacks of process mining in SMMC can be answered. Creating automatic reports to detect undesired behavior in process instances and help to ensure the correct order of events is beneficial. Drawbacks such as the fear of surveillance can be avoided through outlining major benefits of process mining to shopfloor workers, including the automatic documentation of tasks.

RQ3 refers to how the implementation of process mining in SMMC can be designed. As pointed out in Sec. 5, a process model is often already available in the production, generated from the knowledge of the shopfloor workers and process supervisors. Based on the interviews, we conclude that correct process execution and its documentation are of utmost importance. This can be achieved by implementing and executing the existing process model through a process execution engine. The engine is used to orchestrate active process instances of process models and manages the documentation of tasks, i.e., timestamps of start and end events. To give shopfloor workers a better visualization of the process and the currently active task in a process instance, a screen can be used to provide additional information. Utilities, such as a hand scanner or a foot pedal, can be used to automatically complete the current task in a process instance which leads to the next task shown to the worker. A possible setup is the Electroplating process (cf. Sec. 4.1). To increase the knowledge of currently active process instances, wearable information systems can be connected to the process mining framework as well and display process instances not matching the expected behavior [18].

6.4 Discussion

When looking at the significance of the results, three groups can be established.

Not surprising: Digitalization gaps exist and SMMC struggle to close them. All participants agree that explicit process orchestration from the business level to the shop-floor level will improve the quality of available event logs, and is a first step towards online process mining and process enhancement. It became

clear that SMMC suffer from a lack of IT resources. However, they are aware that process mining and data analysis in general will help them with digitalization (i.e., new ways of interacting with their customers).

Expected, but disappointing: Process discovery is not considered important. All participants agreed that process elicitation through explicit modeling leads to better results and understandability. This was not unexpected as SMMC often have flat hierarchies, hence involvement and knowledge of the processes is high. The participating companies (some of the participants also talked about previous employments) often utilize flexible manufacturing islands with unstructured manual labor instead of production lines. The effort for data collection there could very well be so high that focus group participants might be right.

Surprising: Shop-floor workers were expected to be critical of process mining supervising operatives and management alike. However, they were very easily convinced when demonstrating process mining results. Supervising operatives and management wish for the application of process mining on high-level processes, but can neither clearly express the expected results nor have a clear vision how to digitalize these processes. Conformance checking is well understood by the focus group participants. Mining of temporal deviations and performance indicators based on fine-grained sensor data are seen as an important short-term goal. Surprisingly, online process mining, i.e., making deviations visible and explainable at runtime, is considered more important than ex-post analysis.

6.5 Limitations and Threats to Validity

Focus group interviews bear certain threats to validity [10]. In particular, investigating expectations and experiences of process mining in SMMC is relatively complex. Hence, there is a threat of either made up answers, i.e., caused by insufficient experience of a participant or trying to avoid negative feedback by colleagues afterwards, or just trivial answers caused by too many participants. To minimize these threats, we opted for small focus groups, ensured a certain level of knowledge of processes in general, and developed the questioning route following the guidelines in [10]. Further limitations involve:

- *Transferability to other domains:* Manufacturing can be seen as "killer application". Hence it is promising to look at other domains such as medicine that also combine processes, physical world, and human work.
- *Generalizability:* SMMC struggle with specific problems, hence the generalizablity to bigger companies is questionable. Moreover, while a small focus group helps in getting meaningful results for complicated subjects, it can still be argued that similar SMMC are not sharing the same experiences. More interviews with different SMMC could overcome this limitations.

Finally, the companies and participants of the focus group were all volunteers, that answered to an email to a list of companies that regularly participate in research projects. It is possible that (a) the results are not representative of SMMC, or (b) a John Henry effect (over-performance) [17] regarding process mining was observed.

7 Conclusion

This focus group study collected expectations on and experiences with process mining in SMMC, including two real-world process mining scenarios at one company's side. The main findings are:

Suitable data set generation is a main challenge. The status quo in SMMC is that logging is part of the business logic and data-centric. Selected milestones in the production produce a data dump with a timestamp, while most process steps in the manufacturing domain just produce no events at all.

Transparency of business process becomes increasingly important. Transparency is considered important for four key aspects: (a) legal protection against insurance claims, (b) protection against liability claims when dealing with bad parts, (c) reduction of erroneous parts before quality control, and (d) streamlining of processes when dealing with a huge number of product variants in combination with human resources.

Human resources should be included into the process. There is a high level of concern regarding transparency and human resources. Workers may feel observed and become reluctant to share their tacit knowledge. Successful communication and demonstration of the benefits of process mining, on the other hand led to high acceptance among workers.

Infrastructure plays an important role for SMMC. The local IT infrastructure is a perceived bottleneck for the increasing data volume and velocity that comes with fine-grained logging of all steps involved manufacturing and production of goods.

Company `E` successfully introduced process mining in selected scenarios and regards the ability to detect deviations from the process structure, as well as temporal deviations at runtime as a major benefit. This actively helps to minimize the impact of errors, and allows for continuous process improvement to alleviate errors. The increase in transparency was expected and embraced by workers, as well as supervising operatives and management. Demonstrating the reduced documentation effort was the key to winning over workers.

For future work, process mining is to be introduced in company `CDP`. The solution will be implemented based on the findings of this study to meet the expectations of the company and avoid anticipated drawbacks.

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