Process Mining in the Coatings and Paints Industry: The Purchase Order Handling Process

Business Process Intelligence Challenge 2019

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Abstract. The Business Process Intelligence (BPI) challenge is an annual competition in process mining that is co-located with the International Conference on Process Mining (ICPM). BPI 2019 is providing participants with a real event log from the Purchase-to-Pay process of a Dutch company in the field of coatings and paints. The process owner is interested to gain insights into the process from three perspectives. First, discovering various process models referring to different use cases. Second, focusing on throughput time of the invoicing process. Third, detecting deviations based on the expected process model. The aim of this paper is to report the insights and results derived from a comprehensive process analysis using the Celonis Intelligent Business Cloud (IBC). The report also discusses limitations due to process and data characteristics and outlines recommendations for additional data collection and analysis.

Keywords: Process Mining, Process Improvement, Process Discovery, Conformance, Purchase-to-Pay, BPI Challenge, Celonis.

1 Introduction

The Purchase-to-Pay (P2P) process is a challenge for all organizations. This challenge starts with the creation of purchase requisitions and their time-consuming approval processes. It follows with supplier relationship management and ends with handling the invoices and their respective related subprocesses. Thereby, it is crucial for organizations to deal with lack of ownership and maintain good master data on suppliers, enable a proper process and data governance, provide suppliers an automated ordering process, better contract management, and better visibility of payment processing times.

Process mining has proved to be an innovative and efficient method to discover, analyze, and predict business process behavior [1]. For the analysis of the BPI process data, we structure our work by two perspectives. On the one hand, we consider the three main types of process mining including discovery, conformance checking, and enhancement. The process mining types, as described in Figure 1, enable us to discover

the as-is process, to conduct process analytics, and to recommend necessary actions for process improvement.

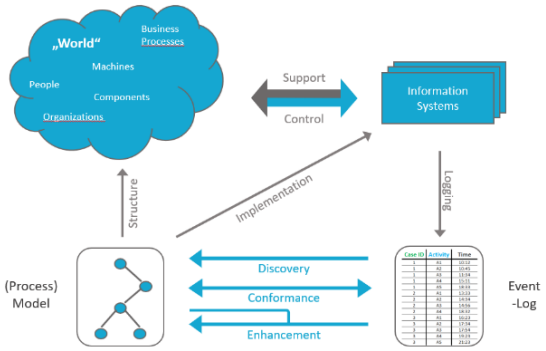


Fig. 1. Process mining overview [1]

On the other hand, and in order to handle the big data provided for the challenge, we consider four types of analysis: Descriptive, Diagnostic, Predictive, and Prescriptive. The descriptive analysis supports us to understand what happened, while diagnostic analysis supports us to understand why it happened like that. The predictive analysis points to what is likely to happen, and prescriptive analysis provides guidelines on what can be done to achieve expected results from the process. The second perspective is adopted from [2] and illustrated in Figure 2.

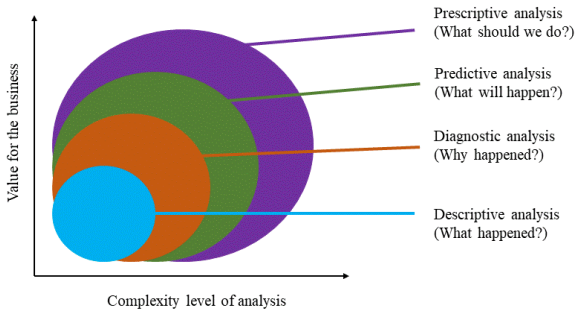


Fig. 2. Four types of big data analytics

The aim of this paper is to analyze the provided process data in order to develop intelligible insights and to answer the process owner's questions. Based on the two mentioned perspectives, we will address these questions as described in Table 1.

Table 1. Analysis overview

No.	Question	Our approach		Conducted Action/Analysis
		First perspective	Second perspective	
1	What is the best collection of process models? - At least four process models needed for four process flows - Best explaining model for each item depends on its properties	Discovery	Descriptive analysis	Process discovery with Celonis discovery algorithm, filtering, and PQL (Process Query Language) functions
2	What is the throughput of the invoicing process?	Enhancement	Predictive analysis, Prescriptive analysis	Cycle time analysis, advanced invoice matching
3	Which Purchase Documents stand out from the log? AND Where are deviations?	Conformance checking	Descriptive analysis, Diagnostic analysis	First-time-right analysis, Celonis features including Conformance checking [7], Process AI and root cause analysis

The remainder of this paper is structured as follows. Section 2 starts with a management summary of the applied analyses, their main findings, and the overall recommendations for process improvement. In Section 3, we explain our understanding of the challenge including the data and the process to show the logic behind our analysis approach. Afterwards, we comprehensively explain the analysis and the results regarding the process owner's questions in Section 4. Section 5 concludes with the limitations.

2 Management summary

Using various process mining methods, we answer the process owner's questions and provide several suggestions with the aim of giving more insights to the process owner. Regarding process discovery, we report one general model that represents the full process along with four additional models representing in-depth views. This process model satisfies four different scenarios including "3-way matching, invoice after goods receipt", "3-way matching, invoice before goods receipt", "2-way matching (no goods receipt needed)", and "Consignment". We also design the models using BPMN notation and use them as a reference model for conformance checking.

Regarding conformance checking, we identify violations to the reference process using root cause analysis and the Celonis Process AI feature along with detecting deviations from the expected process model. We also take advantage of the First-Time-Right (FTR) analysis for further detection of compliance issues. Finally, we approach the enhancement of the process using cycle time analysis.

2.1 Analysis overview

In the following section, we explain the applied analyses as well as the main findings.

Cycle time analysis. With the recent focus on cost reduction, many organizations are forced to identifying opportunities for long-term savings. One way to cut costs is by decreasing the cycle times associated with procuring materials and services. Cycle times provide critical information on an organization's procurement efficiency. With the help of process mining, purchasing organizations can realize shorter cycle times (i) by making their and their suppliers' procurement efficiency transparent, and (ii) by suggesting measures to improve this efficiency

The cycle time analysis on the provided data set and specific activities is summarized as the following:

1. The average throughput time from "Record Goods Receipt" to "Record Invoice Receipt" is 19.9 days; the median throughput time is 9.8 days.
2. The average duration between the creation of the invoice in the source system (Record Invoice Receipt) and the clearing of the invoice is 47.9 days; the median is 41.9 days.

First-Time-Right (FTR) analysis. Procurement quality means that the procurement organization ensures to procure the right product, in the right quantity and quality, in the right place, at the right time, and at the best price. The goal of the FTR analysis is to evaluate how well the purchasing process really works - by calculating how often purchase orders run through the process without being touched by rework to change incorrect orders or recurrent activities. Importantly, those cases that require additional effort are analyzed and their root causes and/or potential drivers are identified.

A main finding from this analysis is that many cases are labeled with their respective classification, however, they are used to clear debit memos created by a vendor. The suggestion here is to create a specific memo clearing process, which enables an accurate conformance calculation for these types of process flows.

Another finding is that for those cases where rework activities occur, the process flow conformance ratio increases. This is interesting as the ROI for additional manual effort can be tracked, i.e. when an employee makes a price change after receiving the invoice, it is done so to comply with the process flow process. It is advised that the company investigates further what the root causes of these changes are, which has already been started with the analysis below.

Conformance checker. The conformance checker allows checking the expected/ideal process model against the process discovered from the recorded data. Conformance checking enables organizations to get an overview of cases that performed correctly as well as detecting the violations that appeared in execution. Conformance checker of Celonis is empowered by the Process AI feature for identifying the root causes assigned to each violation and it supports process analysts to decide on where they should focus on their process improvement initiatives.

Conformance checker and FTR are complementary analyses to answer compliance related questions. The main finding of the conformance checker is designing the expected process model and aligning with the discovered process to detect violations. Additionally, the potential root causes (e.g. EBELP, user, LIFNR, etc.) of process violations are investigated.

2.2 Recommendations on dealing with violations

A main interest of the process owner is to adhere to process compliance. Therefore, we identify dominant violations in the process affecting the performance of each process step. In the following, we explain these violations along with their causes and business impact.

Price changes. Price changes in the procurement process slow down business efficiency, as they are typical rework activities. At the same time, the manual effort associated with price changes significantly increases process costs. Price changes also impact a company's revenue forecast and cash flow and may also indicate unauthorized or inappropriate discounting. Therefore, it is in the corporate interest to detect the root cause of price changes and to take actions against it [8]. Price changes caused by manual users are of highest impact, often resulting from errors in master data or manual entry errors of free-text orders. Manual price changes usually slow down the process and increase the possibility of manual input errors. Free-text-orders refers to Purchase Order (PO) items that have little or no material master data, requiring manual entry of names, codes and prices, which increases the potential of price changes and debit memos. We recommend checking various price change types including multiple price changes as well as price changes that are happening after receiving the invoice, receiving goods, after order confirmation, and before sending the purchase order.

Quantity changes. Quantity changes occur before the goods receipt, e.g. due to an incorrect entry in the purchase order, or after goods receipt, for instance, due to frequently occurring over-runs. The problem with quantity changes in the purchasing process is that they slow down the process, which reduces planning predictability. At the same time, the significant manual effort involved in changing quantities also significantly increases process costs. Therefore, it is recommended to focus on reducing the ratio of orders with quantity changes.

Remove payment block. A smooth and fast process is important in order to pay incoming invoices in time and avoid overdue notices as well as the associated costs of the dunning charges. Setting unnecessary payment blocks, e.g. due to discrepancies within the invoice positions, disturbs the procurement process. It causes longer throughput times, which can result in payments after the cash discount due date or even after the overall due date. In addition, unnecessary payment blocks increase the amount of manual rework activities, which is also associated with higher costs. Therefore, minimizing the amount of unnecessary payment blocks is a desirable objective. For the case of the "3-way match, invoice before goods receipt" however, the removal of the payment block is recognized as a natural part of the process, used for compliance checking.

Cancel invoice receipt. Liquidity is a measure of the ability of a company to meet its current liabilities with its current assets. An important aspect in process efficiency is the avoidance of rework activities on invoice position level as these are often the root of manual effort and slow the process down. In order to ensure a smooth and fast invoice position processing, it is of great interest to identify invoice positions that were correctly processed at the first time and adapt the handling applied in these cases. One

way of increasing liquidity is to investigate the root causes of cancelling invoice receipts and decrease them as much as possible. Some recommendations in dealing with this activity can be described as follows:

- Create a guideline showing the different steps of invoice positions and how to evaluate them.
- Organize training sessions and demonstrate how to implement the best practice and how to evaluate current invoice positions.
- Continuously identify First-Time-Right rates and send out automated reports to all sales and/or accounting employees.

Delete purchase order items. Deleting purchase order items is another rework activity and a barrier preventing a fluid process. It is important to identify and reduce the deleted purchase order items and contact the suppliers. Four important causes of this activity are described as follows. First, the absence of a performance-based reward/penalty scheme with various network vendors. Second, a high dependency on different internal functions as well as suppliers to bring the orders to completion. Third, a high lead time between the receipt of a customer order and the order entry into the respective Order Management System. Fourth, a high number of orders with incomplete or incorrect information. We recommend taking the following actions in order to decrease the occurrence of deleted purchase order items:

1. Assign a responsible team/person, set a response time limit, and set a deadline for resolution.
2. Optimize the work processes across sales, production and logistics to avoid organizational silos.
3. If necessary, reorganize existing processes or add additional ones in order to further reduce error probability.

3 Understanding of the challenge

Business Process Intelligence Challenge 2019 (BPI 2019) has collected data from a Dutch organization and its sixty subsidiaries in the business of coatings and paints regarding their P2P process [3]. In this section, we present our understanding of the provided data and the process. This understanding is the base for the analysis and interpretation of the process in order to better respond to the process owner's questions.

3.1 Understanding of the data

The event logs are provided by the process owner in XES- and as CSV-format [4]:

- XES: https://data.4tu.nl/repository/uuid:d06aff4b-79f0-45e6-8ec8-e19730c248f1
- CSV: http://icpmconference.org/wp-content/uploads/BPIChallenge2019CSV.zip

The data refers to the P2P process excluding approval steps for purchase orders and invoices. The data covers purchase orders submitted in 2018 and includes various categories of services, goods, and different types of vendors. Table 2 presents the attributes of the event logs and their descriptions.

Table 2. Overview of the data attributes

Attribute	Description
Concept:name (Case Key)	A combination of the purchase document ID and the item ID
Purchasing document	The purchasing document ID
Item	The item ID
Item type	The type of the item
GR-Based Inv. Verif.	Flag indicating if GR-based invoicing is required
Goods receipt	Flag indicating if 3-way matching is required
Source	The source system of this item
Document category name	The name of the category of the purchasing document
Company	The subsidiary of the company from where the purchase originated
Spend classification text	A text explaining the class of purchase item
Spend area text	A text explaining the area for the purchase item
Sub spend area text	Another text explaining the area for the purchase item
Vendor	The vendor to which the purchase document was sent
Name	The name of the vendor
Document Type	The document type
Cumulative Value	The cumulative value of the item at each step in the process
Item Category	There are four categories including 3-way with GR-based invoicing, 3-way without GR-based invoicing, 2-way, and consignment

The event log contains 76,349 purchase documents, which includes 251,734 items (251,734 cases). This dataset is suitable to perform various explorative and descriptive analyses of the P2P process.

3.2 Understanding of the process

The purchasing process is a business process that covers activities of requesting, purchasing, receiving, as well as paying for goods and services. There are various processes that are inter-related to perform the full purchasing process. To this end, we can address purchase requisitions and accounts payable as two important processes that are handling the purchasing process from an end-to-end perspective by connecting procurement and invoicing.

The process typically starts when there is a purchase request. The purchase requisition (PR) is a request from employees when they need to make a purchase on behalf of their company. After creating the PR, several approval steps are conducted, and the decision is made whether to accept the requisition. If the requisition is accepted, it will go through the purchasing process.

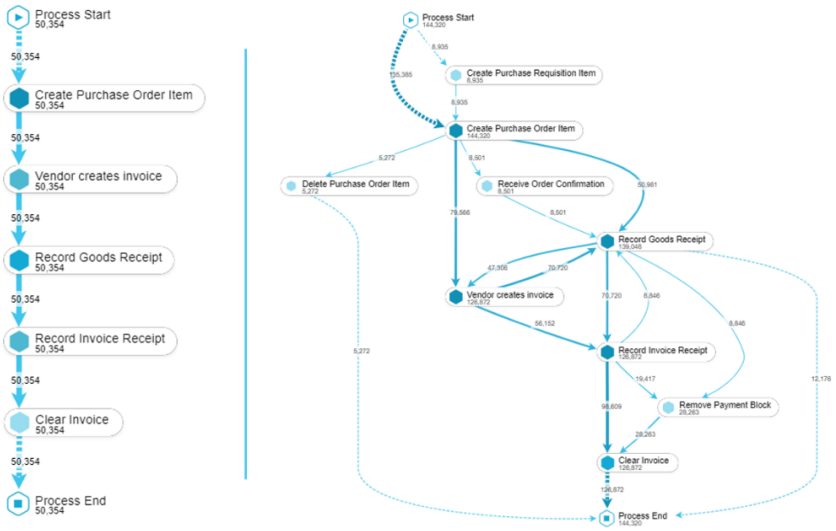
Various roles are participating in the PR processes. The “Preparer” creates purchase requisitions for himself or other users. “Approvers” authorize requisitions based on different rules. “Procurement agents” approve and finalize the requisitions from undefined categories within the supply chain and perform collaborative requisitioning. “Administrators” maintain approval rules and provide basic technical support. PRs are playing an important role from different perspectives. First, they are starting points of the purchasing process and can always serve as evidence of communication among employees as well as suppliers. Second, PRs are used as control tools in order to avoid frauds, such as personal usage of items, as well as controlling if the requested material is needed for the organization. Third, PRs support the centralization of the procurement process

through the purchasing department. This makes the management of the process much easier. When the requisition is approved, it changes from PR to purchase order (PO).

The PO is sent to the vendor, where it is investigated for legitimacy and accuracy, and if it is accepted, the goods are sent to the purchasing company. The invoice of the purchase is created by the vendor either after or before the buyer receives the goods. After receiving the goods, there are two main activities to be performed. The invoice is booked, and the payment is cleared. This part of the process, which is concerned with receiving invoice and payment is also known as Accounts Payable (AP) process. This part of the process is mainly concerned with avoiding late payments to prevent penalties and extra fees.

Using the event logs and connecting the process with Celonis, the main process model (most frequent process flow) is discovered which is shown in Figure 3.

Fig. 3. General process model: most frequent variant (left); nine most frequent variants (right)



According to the models in Figure 3, the activities of the application are perceived as described in the subsequent Table 3.

Table 3. Overview of the process activities

Attribute	Description (our understanding)
Create purchase requisition item	Internal request for items to be purchased.
Create purchase order item	The accepted purchase requests become purchase orders and are sent to the vendor.
Delete purchase order item	Deleting purchase orders. This can be caused by various reasons.
Receive order confirmation	The vendor confirms the receipt of the order.
Vendor creates invoice	Vendor creates an invoice for the ordered items.
Record goods receipt	When the orders are delivered, a receipt will be recorded that proves the order is received.
Record invoice receipt	The invoice of the order is recorded in the system.

Remove payment block	Invoices might become blocked for various reasons. When the issues are solved the blocks should be removed.
Clear invoice	Clear invoice is referring to the complete payment of the orders.

4 Challenge analysis and results

Before conducting detailed analyses, we must understand the main questions of the process owner. Therefore, in this section, we first reflect our understanding of the process owner's questions and identify the most relevant analyses to respond to the questions. These analyses will be presented afterwards along with the results and suggestions for improvement. At the end of this section, we recommend further analyses that could beneficial for this process beyond the challenge.

4.1 Process owner's questions

The provided data covers holistic information on the P2P process; however, the process owner is particularly interested in compliance questions. Accordingly, there are three main questions proposed in the challenge. In this section, we explain each question, reflect our understanding, and suggest the relevant analysis.

Question 1:

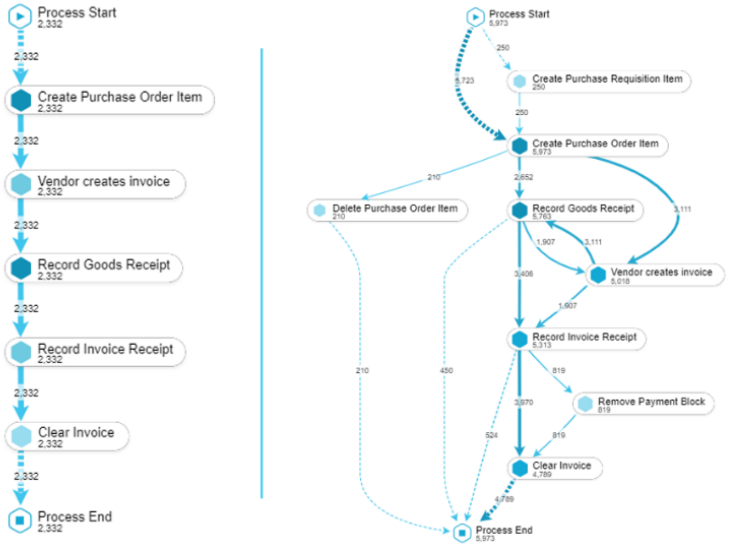
Question. "Is there a collection of process models which together properly describe the process in this data. Based on the four categories above, at least 4 models are needed, but any collection of models that together explain the process well is appreciated. Preferably, the decision which model explains which purchase item best is based on properties of the item."

Our understanding. This question is mainly concerned with discovering the best process model that describes the process accurately. Four categories are recommended by the process owner to be considered in discovering the process as outlined in the following.

1-) 3-way matching, invoice after goods receipt. *"For these items, the value of the goods receipt message should be matched against the value of an invoice receipt message and the value put during the creation of the item (indicated by both the GR-based flag and the Goods Receipt flags set to true)."*

We filter the process on the cases with both "EKPO.GR_VERIF" and "EKPO.GR" values equal to "1", which indicates cases with "GR_based Inv.Verif." flag and "Goods Receipt". This filtering results 15.2k cases out of 252k and the process is discovered as shown in Figure 4.

Fig. 4. Process models (with GR_VERIF & GR): Most frequent variant (left); nine most frequent variants (right)



As presented in Figure 4, the first nine variants of the process model cover 6k cases (referring to 39% of related cases) that show the high level of inefficiencies within the process execution. In addition to the main activities, the model includes extra activities that are not violations such as "Remove Payment Block" (820 cases), which is necessary to be done for the clearing of the invoice. The activity "Delete Purchase Order Item" that happened in 210 cases is considered as an undesired activity.

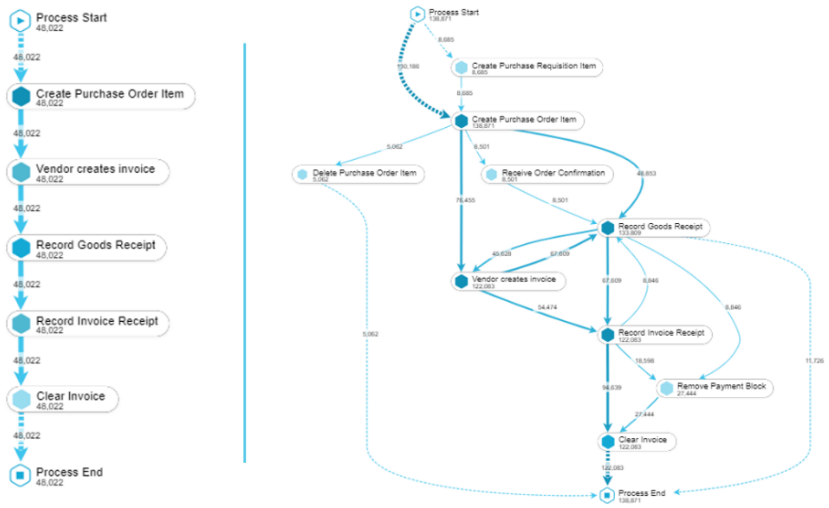
2-) 3-way matching, invoice before goods receipt. *"Purchase Items that do require a goods receipt message, while they do not require GR-based invoicing (indicated by the GR-based IV flag set to false and the Goods Receipt flags set to true). For such purchase items, invoices can be entered before the goods are a receipt, but they are blocked until goods are received. This unblocking can be done by a user, or by a batch process at regular intervals. Invoices should only be cleared if goods are received and the value matches with the invoice and the value at creation of the item."*

We filter the process on the cases with "EKPO.GR_VERIF" value of "0" and EKPO.GR value of "1", which indicates cases without "GR_based Inv.Verif." flag but includes "Goods Receipt". This filtering results 236k cases out of 252k and the process is discovered as shown in Figure 5.

According to Figure 5, the first nine variants of this process model cover 139k cases (referring to 59% of related cases), which shows that there are plenty of inefficiencies within the process execution. Like the process model in Figure 4, the model includes extra activities that are not violations such as "Receive Order Confirmation" (8k cases) and "Remove Payment Block" (27k cases), which are necessary to be done in order to

clear the invoice. However, the activity “Delete Purchase Order Item” is considered as an undesired activity and happens in 5k cases.

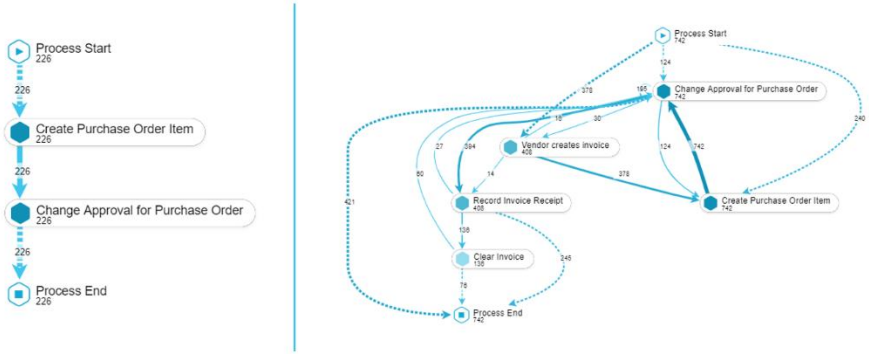
Fig. 5. Process models (without GR_VERIF, with GR): most frequent variant (left); nine most frequent variants (right)



3-) 2-way matching (no goods receipt needed). *“For these items, the value of the invoice should match the value at creation (in full or partially until PO value is consumed), but there is no separate goods receipt message required (indicated by both the GR-based flag and the Goods Receipt flags set to false).”*

We filter the process on the cases with both “EKPO.GR_VERIF” and “EKPO.GR” values of “0” that indicates cases without “GR_based Inv.Verif.” flag and “Goods Receipt”. This filtering results in 1.04k cases out of 252k and the process is discovered as shown in Figure 6.

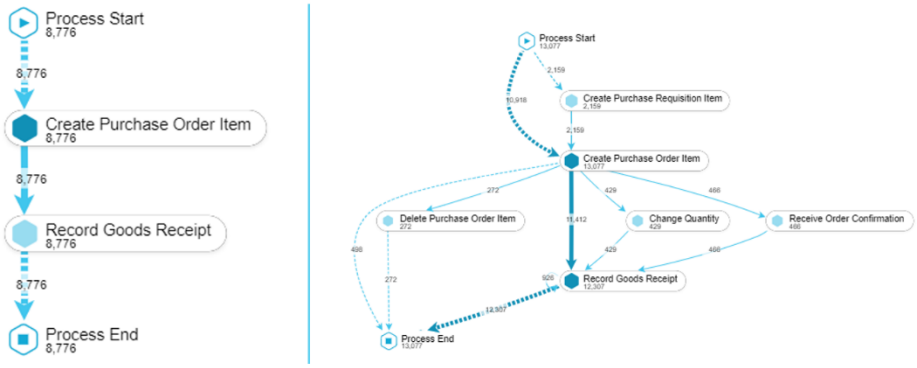
Fig. 6. Process models (without GR_VERIF & GR): most frequent variant (left); nine most frequent variants (right)



4-) Consignment. *"For these items, there are no invoices on PO level as this is handled fully in a separate process. Here we see GR indicator is set to true but the GR IV flag is set to false and also we know by item type (consignment) that we do not expect an invoice against this item."*

We filter the process on the cases with "EKPO.GR_VERIF" value of "0" and "EKPO.GR" value of "1" that indicates cases without "GR_based Inv.Verif." flag but includes "Goods Receipt". Additionally, we filter the process on the material class named "Consignment". This filtering results 14.5k cases out of 252k and the process is discovered as shown in Figure 7.

Fig. 7. Process model (consignment material class, (without GR_VERIF, with GR): most frequent variant (left); nine most frequent variants (right)

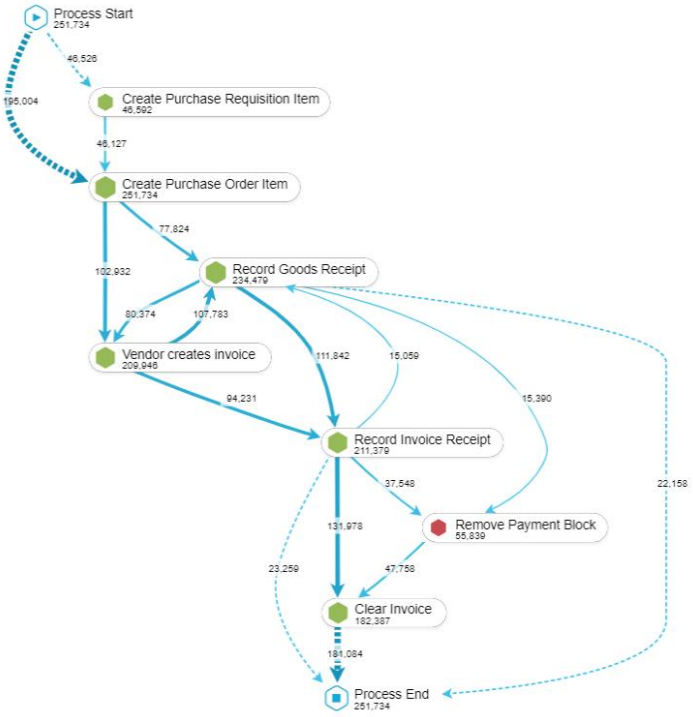


According to Figure 7, the first nine variants of this process model cover 13k cases (referring to 90% of related cases). This process model also includes an extra accepted activity of receiving order confirmation as well as two undesired activities including deleting purchase order item (269 cases) and changing the quantity (431 cases).

Considering the discovered process models, we design a model that describes dominant process instances. This process model is considered as an ideal process model to be used in conformance checking as well in order to detect process violations. The discovered process model is presented in Figure 8.

The process starts with either creating a purchase requisition or creating a purchase order item. Three activities including "Record Goods Receipt", "Vendor Creates Invoice", and "Record Invoice Receipt" can be performed in three sequences. The purchasing organization might either first receive the goods and then the invoice that is created by the vendor or the vendor first creates invoice and then sends the goods to the organization. Additionally, the process can follow to the end point after receiving goods in case of dealing with consignment material group. The activity "Remove Payment Block" is not a desired activity in an ideal process model, however it is a necessary step for clearing the invoice if a block has been set for the conformance reasoning laid out by the "3-way match, invoice before goods receipt" process flow.

Fig. 8. Process model summary of four scenarios



Question 2:

Question. "What is the throughput of the invoicing process, i.e. the time between goods receipt, invoice receipt and payment (clear invoice)? To answer this, a technique is sought to match these events within a line item, i.e. if there are multiple goods receipt messages and multiple invoices within a line item, how are they related and which belong together?"

Our understanding. The second question is concerned with throughput time, mainly of the second part of the process, which relates to invoicing. For instance, the throughput time of a sub-process that starts with the activity goods receipt ("Record Goods Receipt") and ends with the payment activity ("Clear invoice"). Accordingly, we conduct two groups of analyses that are directly referring to this question: "Cycle time" and "Advanced invoice matching".

Invoice processing is a sub-process of the P2P process. Considering the invoicing process, the cycle time analysis provides critical information on the efficiency of incoming invoice management. With the help of process mining, these cycle times can be monitored and analyzed. Bottlenecks and inefficiencies can be recognized easily and

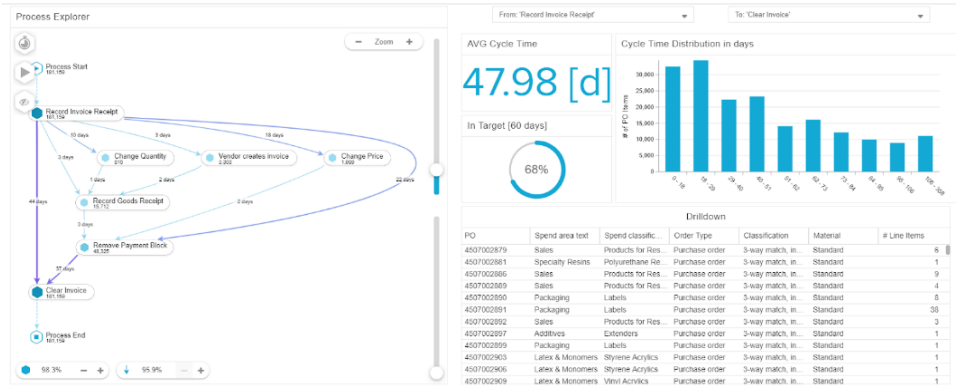
quickly. Provided with these insights, accounting departments can optimize their accounts payable and thus realize faster processes and reduced turnaround times. This analysis focuses on the time between the entering of incoming goods and the payment of their related invoices. This segment is particularly important as, e.g., paying dunning charges for late payments can lead to a considerable decrease in the liquidity. Therefore, the analysis of the cycle times between the "Record Goods Receipt" and the invoice payment, as well as the avoidance of so-called "long-runners", are essential.

Accordingly, we initially transform the data into a usable format through the Celonis Event Collection. We then start by deleting "Clear Invoices" that are not clearings as the corresponding invoices have been cancelled. Having a look at the process, we noticed that in most cases the clearing took part almost immediately after the invoice was cancelled. As we do not have sufficient information, we decide that clearing invoice right after the invoice cancellation would be deleted, as either the case contained more than one or there were legitimate clearings in it. This is achieved by self-joining the activity table and looking at the time differences between the stated activities per case. Having removed the false clearings, we need to change the activity name of receipts.

In order to calculate cycle times, we exclude goods and invoice receipts that are cancelled later in order to avoid mismatches. As mentioned previously, due to available information, we assume that the cancellation of received goods always relate to the most recent goods reception. Therefore, using a window function, we are able to determine which receipts are cancelled by looking at preceding receipts and ordering them. Afterwards, we rename the first activity of the list. This is repeated until the number of cancellations is identical to the number of receipts to be cancelled.

After having all the prerequisites, we create a formula that is used to calculate the cycle times. To achieve this, we utilize the Celonis built-in Process Query Language (PQL) functions, namely the Pull-Up-Functions. This function allows us to aggregate a column based on another table. We define the parent table to which the child-tables entries are pulled, and explicitly define on which basis calculations are executed. Using the activity table as both parent and child table, we are then able to pull up the event times for each activity ordered by their occurrence in time, to determine the time that is passed.

Fig. 9. Cycle time analysis



As output of the described steps, we can build an analysis to tackle the questions asked by the process owner. It has been mentioned in the management summary that the average throughput time from “Record Goods Receipt” to “Record Invoice Receipt” is 19.9 days; the median throughput time is 9.8 days. Also, the average duration between the creation of the invoice in the source system (Record Invoice Receipt) and the clearing of the invoice is 47.9 days; the median is 41.9 days.
Taking a payment target of 60 days into account, 68% of cases are paid within this timeframe (from “Vendor creates invoice” to “Clear invoice”). Next to the possibility of supplier dissatisfaction and risk of facing non-favorable supplier conditions, the late fee rate of 3% is the industry standard.

Invoices, for which the payment needs 30 months or longer (90 days or more), can be specified as long runners. These invoices account for 12% (or 48,960) of all invoices and take on average 107.8 days to be completed. Especially the scenario of “3-way match, invoice before goods receipt” is a main root cause for these long runners, which is accounting for 99%. Additionally, another root cause for long runners is the material group “Labels”, 85% of invoices are due to this spending, while in total they account for 23%, which falls under the spend area “Packaging”.

Question 3:

Question. “Finally, which Purchase Documents stand out from the log? Where are deviations from the processes discovered in (1) and how severe are these deviations? Deviations may be according to the prescribed high-level process flow, but also with respect to the values of the invoices. Which customers produce a lot of rework as invoices are wrong, etc.?”

Our understanding. Using the Celonis Conformance Checking feature [7] along with FTR analysis allows us to address the third question that is mainly concerned with business process deviations.

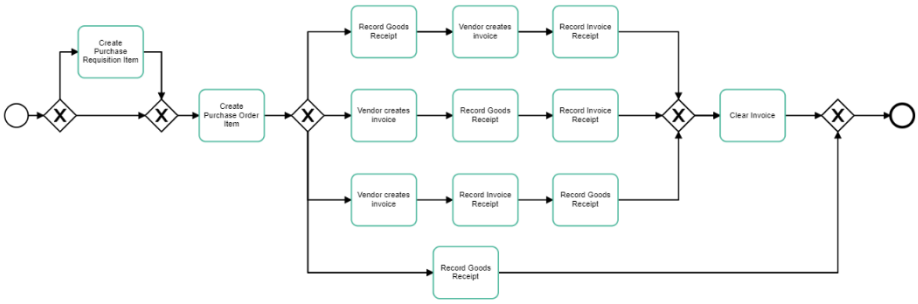
Conformance checking analysis is very useful to find deviations from the discovered model and point to the impact of each deviation. This analysis satisfies the high-level process flow as well as the four main process scenarios. The conformance checking analysis allows us to automatically check a reference process model (modeled by the organization or captured from standard frameworks) against the discovered process model from the extracted data. This analysis provides various information by comparing the two models. Some of the important findings can be addressed as follows:

- Statistics on conforming and non-conforming cases according to the reference model,
- The number of violations from the reference model and violation root causes
- The influence of violations on predefined KPIs (e.g. throughput time)
- Conforming cases trend over time

Conformance checking is a promising analysis for finding the inconsistencies between expected process model and the executed event logs. This analysis provides good insights on what can be changed within the process in order to fit the expected process model [5].

The expected process is modeled using BPMN language (Figure 10) that represents the ideal process. We use it as a reference model for conformance checking and detecting deviations.

Fig. 10. The expected process model



After modeling the expected process model and launching the conformance checking analysis, we must carefully check the list of violations and whitelist the possible incorrectly detected violations. This refers to activities that were considered as undesired steps but are instead accepted, such as "Receive Order Confirmation" and "Record Service Entry" or potential accepted sequences of activities such as "Vendor creates Invoices" followed by "Record Goods Receipt".

Aligning the event data and the reference model results in 155k conforming cases against 96.7k non-conforming cases and 56 violations can be detected in the process model. In the ideal process, we expect the invoices to go smoothly from "Record Invoice Receipt" to "Clear Invoice". However, there are issues appearing for invoices and in many cases, they have been blocked. Setting unnecessary blocks, e.g., due to discrepancies within the invoice positions, disturbs the process. This causes longer throughput times which can result in payments after cash discount due date or after the overall due date. In addition, unnecessary payment blocks increase the number of manual rework activities which is also associated with higher costs.

An overall investigation of violations for the general discovered process model using Celonis Process AI feature shows that root causes are mainly related to specific dimensions such as "Item Number of Purchasing Documents (EBELP)", "User_Name", "Vendor (LIFNR)", "Purchasing document type (BSART)", and "Material group (MATKL)". After conducting the conformance checking analysis, the top-ranked violations are reported as several undesired activities including "Remove Payment Block", "Change Quantity", "Change Price", "Cancel Invoice Receipt", and "Delete Purchase Order Item".

Using Celonis Process AI, we further discover that in the dominant violations, the main purchasing document type (BSART) is "standard PO" and the assigned material

group (MATKL) is mainly from three categories including “Standard”, “Subcontracting”, and “Consignment”.

Out of all violations, “Remove Payment Block” as an undesired activity is a dominant violation with 22% of cases (58,839 cases). This activity affects the throughput time for 26 days longer. Accordingly, we investigate the root causes and find that most of these violated cases are assigned to the “Item Number of Purchasing Documents” 30 and 40 with 4k violations. Table 4 summarizes the conformance checking results and three related root-causes including “Item Number of Purchasing Documents (EBELP)”, “USER_NAME”, and “Account Number of Vendor or Creditor (LIFNR)”.

Table 4. Overview of the process violations

Violations	#Cases	Potential root causes
‘Remove Payment Block’ is an undesired activity	22%	• EBELP = 30, 40 - 4K violations • USER_NAME = user_015, user_006, user_023, batch_02 - 20K violations • LIFNR = vendorID_0136, vendorID_0104 - 7K violations
‘Change Quantity’ is an undesired activity	7%	• EBELP = 10, 20, 30 - 6K violations • USER_NAME = user_084 - 2K violations • LIFNR = vendorID_0136, vendorID_0197 - 2K violations
‘Change Price’ is an undesired activity	4%	• EBELP = 10, 20 - 4K violations • USER_NAME = user_071, user_037, user_038, user_039 - 3K violations • LIFNR = vendorID_0236, vendorID_0197 - 1K violations
‘Delete Purchase Order Item’ is an undesired activity	4%	• EBELP = 10, 40 - 2K violations • USER_NAME = user_252, user_060, user_158 - 825 violations • LIFNR = vendorID_0104, vendorID_0106 - 1K violations
‘Cancel Invoice Receipt’ is an undesired activity	3%	• EBELP = 10 - 2K violations • USER_NAME = user_015, user_004, user_013, batch_01 - 2K violations • LIFNR = vendorID_0118 - 389 violations

Additionally, we apply the conformance checker for the four discovered process models to be compared with the expected process.

First, taking the process model of ***“3-way matching, invoice after goods receipt”*** into consideration results in 9.13K conforming cases against 6.05K non-conforming cases. In addition to “Remove Payment Block”, “Change Quantity”, “Change Price” as undesired activities, another violation is referring to cases that “Clear Invoice” is followed by “Record Goods Receipt”. The later sequence might happen if the invoice is being cleared partially after receiving a good partially. However, the lack of information in the data does not allow us to separate partial payments from the rest.

Second, taking the process model of ***“3-way matching, invoice before goods receipt”*** into consideration results in 147k conforming cases against 88.6k non-conforming cases. Along with the main introduced violations, 2% of the non-conforming cases in this process model are violated by “Vendor creates debit memo” as an undesired

activity. Additionally, the process owner might consider that "Remove Payment Block" is not necessarily an undesired activity in all scenarios. For instance, in this process flow, a payment block is created at the time of invoice receipt, to ensure that the goods are not paid for until they arrive. This exception is considered in the FTR analysis.

Third, taking the process model of ***"2-way matching (no goods receipt needed)"*** into consideration results in 1.01k conforming cases against 37 non-conforming cases. Along with the main introduced violations, "Set Payment Block" is also as an undesired activity. Decreasing the occurrence of setting payment blocks will cut costs and increase the speed of the process.

Fourth, taking the process model of ***"Consignment"*** into consideration results in 149k conforming cases against 86.7k non-conforming cases. Like in the process model of "3-way matching, invoice before goods receipt", "Vendor creates debit memo" is an undesired activity along with the main violations.

Along with conformance checking, we use FTR analysis in order to drill down the process and get insights about invoices and customers. FTR combines rework (activities that should not happen in the process even once, e.g. "Removing payment blocks" or "Change quantity") and recurrent activities (i.e. those activities that occur more often than they should, e.g. more occurrences of "Record Invoice Receipt" than of "Record Good Receipt".

Having assessed the most common rework activities and then the data flow conformance, this section starts by filtering on non-conforming data flows and then gains insights from there. Most of these non-conformances come from the spend area of logistics (514 from 532 cases, 96.6%), of which 444 cases were in the sub-spend areas of "Road Packed" (86%), 50 cases in "Other Logistical Services" (9.7%) and 19 cases in "Sea" (3.9%). The most frequent vendors involved are: vendorID_0538 (77 cases, 14.5%), vendorID_0233 (76 cases, 14.3%), and vendorID_0535, vendorID_0540 & vendorID_0541 (48 cases each, 9% each). The most frequent users, i.e. those that appear in the most number of cases, are: user_002 (458 cases, 86%), user_200 (357 cases, 67%), user_001 (140 cases, 26%), user_012 (128 cases, 24%), user_013 (114 cases, 21%).

The main root cause of this non-conformance is that the goods receipt value does not match that of the PO creation value or invoice receipt value, with all non-conforming cases resulting from this, across both FTR and not-FTR cases. Interestingly, the value from the activity "Vendor creates invoice" is more often not correct, i.e. not equal to that of the clear invoice activity.

The FTR principle is a quality management concept that states that designing a process that minimizes defects is more cost-effective than one that includes defect detection and associated corrective rework efforts [6]. An important aspect of purchase efficiency is the avoidance of rework activities as these are often the root of additional manual effort, longer process throughput times and lost opportunity. In order to ensure a smooth and fast purchase order processing, it is of great interest to identify the ratio of purchase orders that were correctly processed the first time compared with those that were not, using this as a main KPI to improve over time. With the help of process mining, orders not considered as FTR can be spotted easily and quickly, and their root

causes can be identified. Provided with these unique insights, businesses can optimize their P2P process to save time and money by effectively reducing causes of process inefficiencies.

In order to produce a meaningful analysis, the following filters and classifications are applied to the data set:

1. Not considering consignment cases, only cases that flowed through the "Clear Invoice" activity are considered in the FTR analysis. This reduces the potential of early-stage open cases to skew the FTR results, e.g. cases where only a Purchase Order has been created would be considered as FTR, which is a poor indicator of its performance as many other process activities are still yet not done.
2. Only cases created during the year of 2018 are considered in the analysis.
3. The following activities are added to the "Whitelist", i.e. a list of the activities that will not trigger a violation to FTR, should only occur once per case: "Clear Invoice", "Create Purchase Order Item", "Create Purchase Requisition Item", "Receive Order Confirmation", "Record Goods Receipt", "Record Invoice Receipt", "Record Service Entry Sheet", "Vendor creates invoice".

Note, there are some special cases where the whitelist is altered slightly, however these will be explicitly stated in the respective analysis section.

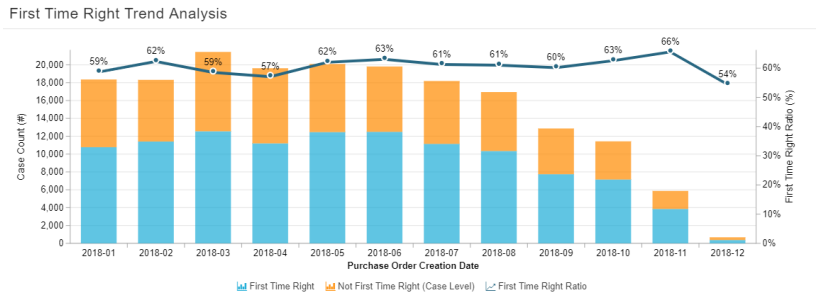
All activities not included in the whitelist are considered as rework activities, and thus if they occurred even once per case, the case is not considered as FTR. Additionally, if those activities in the whitelist occur more than once per case, the case is also not be considered as FTR. Furthermore, whilst classifying cases into either FTR or not, we count the amount of rework activities and recurrent activities per case, allowing the severity of an FTR violation to be set. This has two benefits: (i) It enables the analyst to identify irregularities that require filtering or data cleaning, and (ii) it ultimately enables the client to identify the most problematic activities in their process, thus allowing for data-driven transformation initiative prioritization. With FTR as defined above, and the respective predefined filters also set, the data yields 111,470 FTR cases from a total of 183,677 cleared cases, meaning the FTR ratio of 60.7%.

The FTR ratio is plotted over time, enabling a visual understanding of any trends that may be present over time. As becoming apparent in Figure 11, there is a relatively consistent ratio of FTR cases distributed throughout the year. An interesting observation is that even though there are few cleared cases towards the end of the year, 17,976 in the last quarter compared with 58,120 in the first quarter, their FTR ratio differs by only 3%, 63.2% compared with 59.8% respectively. This provides an indication that purchase order volume may be only slightly correlated with FTR.

When considering only those cases that are not-FTR (72,207), it is obvious that rework activities are much more significant to their classification than recurrent activities, with 94.7% of not-FTR cases including rework activities compared to only 22.0% of not-FTR cases that include recurrent activities. Due to the specific nature of the company's purchasing model however, these numbers could be misleading. As discussed in the briefing document, the data flows go beyond the four categories described, and involve multiple goods receipts, payment blocks and invoices per case. This adds complexity to the FTR analysis, as recurrent activities are actually permitted (e.g. multiple

goods receipts and invoice receipts). Thus, in order to provide more meaningful insights, the analysis is categorized into the four types of flows discussed within the assignment brief, enabling more specific filters to be applied.

Fig. 11. First-Time-Right (FTR) trend analysis



First, for the process flow ***"3-way Matching, Invoice After Goods Receipt"*** to be conformant, the invoice should be received after goods receipt, and the value at PO creation should be equal to those at goods receipt and invoice receipt. When considering this process flow, 9,554 cases flow through the activity "Clear Invoice", of which 5,851 (61%) cases are classified as FTR and 9,022 (94%) cases are process flow conformant. When filtering on cases conforming to FTR, the data flow conformance drops below the average, to only 92%. Of the not-FTR cases, had a higher than average process flow conformance, with 3,643 conforming cases compared to 60 non-conforming (98.3%).

A total of 7,959 rework activities are present in these not-FTR cases, with "Change Price" as the most frequent with 1,106 activities (14%) across 972 cases (26% of all cases). Interestingly, when filtering for cases that include a price change, the conformance to the data flow jumps to 99.8%, indicating that this rework activity is performed to attain data flow conformance. This additional effort enables the business to be conformant in 970 of the 972 cases. One of the two cases, "4508071078_00010" is non-conformant as the invoice is cleared, however no goods are received, with an item value of 334 Euro. The other case, "4507015727_00010" is non-conformant as the "Goods Receipt" value (66,995 Euros) does not equal that of the PO Item or clear invoice value (33,497 Euros), and thus it should not have been cleared.

The second most frequent rework activity, "Change Quantity" is present in 689 cases, occurring a total of 790 times. Of the cases that have this activity, the data flow conformance ratio is 99.9%, with only one case non-conformant. The violation occurs in the same case as one of the price change violations, "4507015727_00010", with the same user (User_171) responsible. Interestingly, the value of the activity "Vendor creates invoice" is in fact the PO item value and the clear invoice value, which may indicate a user entry error, or a field automation error.

The third most frequent rework activity, "Cancel Invoice Receipt" occurs 649 times across 418 cases. The vendors whose invoice receipts are cancelled most often are: vendorID_0236 (78 cases & 80 occurrences), vendorID_0470 (43 cases & 43 occurrences), vendorID_0157 (26 cases & 41 occurrences), vendorID_0404 (23 cases & 27 occurrences) and vendorID_0183 (16 cases & 18 occurrences) - accounting for 45% of

the cases. With this activity present, the data flow conformance rises to 98%, with 9 cases in violation. Case “4508046522_00001” appears to be the most serious violation, due to the cumulative net worth equaling over one million Euros at multiple stages in the process, although the PO item was valued at only 1,582 Euros at creation. Three invoices are recorded during this case, with only one of them being cancelled, and only one being cleared after the removal of a payment block. Case “4507007756_00001” is cleared even though no goods receipt was recorded, the goods receipt values for case “4507010781_00001” differed from the PO and invoice clearing value, case “4508046183_00001” begins with the invoice creation and looped multiple times between goods receipt and record service entry activities, and the goods receipt value differs from the clear invoice value.

Second, the process flow ***“3-way Matching, Invoice Before Goods Receipt”*** corresponds to the vast majority of all cases within the data set, with a total of 173,536 flowing through the clear invoice activity (95% of all cleared cases) and a FTR ratio of 87%. For this data flow to be conformant, the value at PO item creation must match that of the value at clear invoice, and a goods receipt has to occur prior to clearing. The conformance ratio to this data flow is 99.69% (172,008 conforming cases). From all the cleared cases, there is a total of 6,293 variants from the happy path, whereby the FTR cases have 95 distinct variants, and the not-FTR cases have 6,198 variants.

For FTR cases, the process flow conformance ratio jumps to 99.96%, with only 53 non-conforming cases out of 143,200 cleared cases. These non-conforming cases mostly come from vendorID_0660 whom is responsible for 37 of the violations, of which 32 cases are cleared without a goods receipt and 5 are cleared prior to goods receipts. Surprisingly all values at PO creation matched the cleared invoice values, which indicates that a conformance check was performed on the values, but not on the process itself. All other non-conforming cases result from the same issue, whereby the invoice is cleared prior without goods receipt.

For the not-FTR cases, the process flow conformance ratio drops slightly to 98.10%, whereby 474 out of 24,972 cases are classified as non-conforming. In 472 of these cases, the invoice is cleared even though the goods are never received, and in the other three cases, the goods receipt happens after invoice clearing. Like the FTR cases, the values at PO creation match those at invoice clearing in every single case. The most frequent manual rework activities are: “Cancel Invoice Receipt” - occurring 467 times across 454 cases, “Vendor Creates Debit Memo” - occurring 459 times across 456 cases and “Cancel Goods Receipt” - occurring 275 times across the same number of cases. These rework activities are all caused by the vendor’s debit memo, which may stem from the vendor incorrectly invoiced the company in the past or over-delivering goods. The rectification of these issues takes place within a procurement sourcing process, even though it is of a different nature to the second process flow. As this use case differs from that of the desired data flow, it is recommended to the customer that they change their process, or incorporate a new field, that allows for a rectification to be identified. Further, as these rectifications involve manual rework to the company, it is important to note that the vendor with the most cases for these issues is vendorID_0246, responsible for 232 cases (49%). The spend areas most influential in these non-conformances

are: “Trading & End Products” - 263 cases (55%), “Sales” - 107 cases (23%) and “Packaging” - 68 cases (14%).

From the 24,972 not-FTR cases, there are a total of 199,247 activities, of which 40,937 (19%) are manual rework activities. The most frequently occurring manual rework activities, by case count, percentile of all cases, occurrence count, occurrence ratio, the number of non-conforming cases that include the activity and the process flow conformance ratio of all cases that include the activity, are shown in Table 5.

Table 5. Rework activity metrics

Activity name	Case count	% of cases (Not-FTR)	Rework activity count	% of all rework activity	Non-conforming cases	Process flow conformance ratio
Change Quantity	11846	47.4%	14536	35.5%	19	99.84%
Change Price	7985	32.0%	8909	21.8%	92	98.85%
Vendor Creates Debit Memo	4680	18.7%	4801	11.7%	456	92.26%
Cancel Invoice Receipt	4243	17.0%	4544	11.1%	454	89.30%
Change Approval for Purchase Order	1595	6.4%	2472	6.0%	0	100%

The activities “Change Quantity”, “Change Price”, and “Change Approval for Purchase Order” all have a positive impact on the process flow conformance, whereby the cases including these rework activities are conformant above the average not-FTR value of 98.1%. The other activities are by nature non-conforming, and result from issues on the vendors side, such as using the wrong rates when calculating line values or sending an oversupply of stock.

The median throughput time between “Create PO item” and “Record Goods Receipt” of not-FTR cases for this process flow type is 16 days. Interestingly, the median time between “Create PO item” and “Change Quantity” is 12 days, and when this activity is present the median time between PO creation and goods receipt increases to 21 days. So for cases without the activity, goods arrive sooner. The fact that quantity changing occurs 12 days after PO creation (median could be interpreted as late changes of POs. A root cause might be that POs are created too far in advance for accurate planning, and thus required changes (increases or decreases) closer to the time of goods receipt. In these cases, the throughput time increases, which is harmful for purchasing planning. There could be some reasoning to create a PO as a type of “blocker” in the vendor’s system, and then change it with improved accuracy when it is closer to the date when the goods are actually needed. However, depending on the vendor lead time, it may also make sense to simply order items closer to when they are needed, which reduces additional effort and enables a more streamlined purchasing process.

Price changes have less impact on throughput times than quantity changes, however they have a significant impact on manual rework, and thus create risk for overpayments. The vendor “VendorID_0197” is involved in the most violations, accounting for 911 price changes across 766 cases. The process flow conformance ratio is 100%, indicating the integrity of the review process implemented in the company. With more data it

would be possible to understand whether the price changes come from the vendor or the business, enabling root causes to be identified: such as master data issues, typos, unit price scaling errors and more.

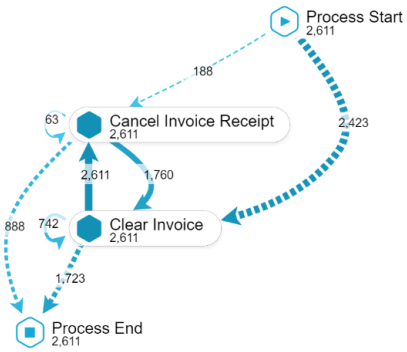
Third, the process flow ***"2-way matching (no goods receipt needed)"*** is considered conformant if the value of the invoice is equal to the value at creation. These types of process flows are small in numbers, only accounting for 297 cleared cases, of which all were considered conformant to the respective data flow. These cases contain the rework activity "Change Approval for Purchase Order". The spend area "Real Estate" is the most accountable, with 222 violations (75%) and 1,084 PO approval changes. The most expensive PO came from EBELN: 4507075967, with three-line items totaling to 451k euros. Due to the value of these cases, the additional rework effort is most certainly justified. Interestingly, the only two users that make the activity changes are User_602 and User_603.

Fourth, as the process flow ***"Consignment"*** does not consider invoices on an item level, the invoice activities (such as invoice receipt and clearings) are not present. So far, the FTR formula analyzes only cases where the clear invoice activity is present, which is not significant for this flow type. Thus, the end activity was adjusted to "Record Goods Receipt", meaning only cases with this activity are analyzed. With this logic applied, a total of 13,466 cases are closed, of which 12,028 (89%) are labelled as FTR. As this data flow does not have values assigned to PO items, further process flow conformance is not possible, similar as for the previous data flows.

5 Limitations

Limitations are in the essence of each project. Our analysis and findings are also limited to the provided data and information availability. We had complications that might refer to noisy data but also lack of information on the process steps that might lead to process misunderstanding. For instance, there are 2,611 cases that are canceling the invoice receipt after clearing the invoice and 1,760 cases that are clearing the invoice after canceling the invoice receipt (Figure 12).

Fig. 12. Process graph showing invoice canceling after clearing and clearing after canceling



Additionally, we can refer to data anonymization that limits comprehensive understanding of the data. However, we have tried to get the most knowledge possible out of the provided data and within the limited time. We hope that our findings would support the process owner in their process transformation initiatives.

Finally, process mining is a powerful tool to analyze and understand business processes. However, the findings generated should be interpreted cautiously (especially regarding direct actions taken on the basis of process mining insights), as correlation does not necessarily imply causation.

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