

Design of the structure accounting and contractual process of the Fabrica de Licores de Antioquia - Colombia, through process mining.

Isaac Mauricio Gaviria Martínez¹, Yeraldin Beltrán Linares², Jhon Wilder Sanchez-Obando³ and Néstor Darío Duque-Méndez⁴

Abstract

In today's business environment, it is crucial to have systems that can analyze, diagnose, enhance processes, and optimize organizational outcomes. Currently, there is limited research related to process design using process mining algorithms, such as the Alpha algorithm. This highlights the significance of validating the interaction between two fundamental axes of a company: the accounting and budgetary processes versus the contractual processes. These are among the most critical components at the Liquor and Alcohol Factory of Antioquia in Colombia, where agility and assertiveness are paramount in each contracting process to prevent delays in production. This paper introduces a methodology that includes an analysis of the annual procurement plan, along with its corresponding accounting entry and budgetary item, based on process mining. The objective is to identify deficiencies originating from the accounting and budgetary processes. The research results in a methodology for implementing process mining in organizational management, which facilitates the identification of various bottlenecks in budgetary items due to the volume of contracting, as well as the constraints that some programs face when managing the provided databases. Process mining offers a robust alternative to traditional process modeling frameworks like BPMN.

Keywords: Process mining, organizations, process

1. Introduction

Today's enterprises are equipped with a multitude of Enterprise Resource Planning tools that help consolidate the vast amount of information handled, as noted by Blount et al., (2016), and reduce the time required to generate and interpret reports. However, beyond the functional perspective, there are numerous outcomes that are often overlooked and could potentially reveal biases in information and process execution, which become challenging to identify due to operational complexities.

Van der Aalst, (2011) points out that today's systems like data mining and process

¹ Universidad de Manizales. Facultad de ciencias contables, económicas y administrativas. Maestría en Finanzas. imgaviria102428@umanizales.edu.co, imagavi@hotmail.com

² Universidad de Manizales. Facultad de ciencias contables, económicas y administrativas. Maestría en Finanzas. yerabel12@hotmail.com

³ Universidad de Manizales. Docente investigador de la Facultad de ciencias contables, económicas y administrativas. jwsanchez@umanizales.edu.co

⁴ Universidad Nacional de Colombia sede Manizales. Facultad de Administración, Líder del grupo de investigación GAIA. ndduqueme@unal.edu.co

mining enable the analysis of large databases that, due to their volume and extensive variability, are complex to process and analyze; yet, they ultimately organize information more effectively and yield more refined material for analysis with greater accuracy (van der Aalst et al., 2007). While this practice has a long history, it is only in the 21st century, thanks to advances in computing technology, that ordinary people can utilize this powerful tool to perform complex analyses of their administrative processes.

In its early stages, process mining focused on developing techniques and algorithms to extract knowledge from event logs. However, in recent years, it has evolved into a more mature discipline that addresses both the technical and practical aspects of applying process mining in business environments.

There is still much to be achieved in fully exploiting the benefits of process mining, which this study aims to address by showcasing these underexplored benefits based on the analysis of methods and procedures used daily at the Liquor and Alcohol Factory of Antioquia. Process mining links all elements that are interconnected through the interaction of activities developed in an area. It analyzes the flow of information packets that travel during an action, creating a more visible and useful image for establishing criteria to improve the outcomes of different processes.

Faced with new business challenges, one might question: Are the contracting processes efficient and effective? Are the accounting and budgeting processes truly aligned with the efficiency and efficacy needed to expedite contracting processes?

The contracting process of the company is one of the most influential factors in being more competitive in the market. It must respond timely to market needs and therefore must have a process that prevents concentrations of events that could jeopardize the response times of the contracting process.

This work is structured to review and apply process mining and how it has positively impacted today's industry. Accordingly, Section 2 presents the state of the art and related work, Section 3 describes the methodology applied to this study, Section 4 discusses the results obtained, Section 5 addresses the discussion, and finally, Section 6 concludes with the findings and limitations encountered.

2. State of art

Within the realm of process discovery, the automatic identification of process models from event logs has been an active area of research. Algorithms such as the Alpha Algorithm, the Heuristic Process Mining Algorithm (Heuristic Miner) by Weijters et al., (2006), and the Inductive Miner (Leemans et al., 2013) have been studied and applied in various contexts, providing solid foundations for the analysis of Business Process Management Systems (BPMS).

Moreover, the study also involves the analysis of deviations and process improvement where the detection of deviations and the analysis of process variability have been significant areas of research. Techniques such as conformance checking by Rozinat & van der Aalst, (2008) and variability analysis by Adriansyah et al., (2011) help identify discrepancies between the expected process model and the actual process behavior, enabling continuous improvement.

This evolution has led to more effective process visualization of process models and log data, as noted by Sirgmets et al., (2018) . It is crucial to facilitate understanding and analysis. Vom Brocke & Rosemann, (2015) highlight that tool like ProM, Disco, and

Fluxicon have been developed to provide intuitive interfaces with advanced visualization capabilities, which, according to Knobbout et al., (2023), assist in processing real-world information and data.

This has extended to industrial applications of process mining as articulated by Van der Aalst, (2011). With the aid of various Enterprise Resource Planning systems, it has been successfully applied across a broad range of sectors, including healthcare as noted by Rojas et al., (2016), banking, manufacturing, and public services. Case studies have demonstrated how process mining can identify bottlenecks and, as Mahendrawathi et al., (2017) mention, improve efficiency and reduce operational costs in various organizations.

2.1. The Alpha algorithm for process mining

Process mining has emerged as an essential tool for analyzing and enhancing the efficiency of industrial processes across a variety of sectors. Significant studies have been conducted on manufacturing processes, as highlighted by Van der Aalst & Weijters, (2004), suggesting that process mining has been successfully applied in manufacturing to conduct objective analyses, optimize resource utilization, and improve product quality. Further research by Mahendrawathi et al., (2017) demonstrates how process mining can be utilized in the manufacturing industry to enhance production efficiency.

Real-time process monitoring and control are increasingly being developed thanks to the powerful process mining algorithms. In the healthcare sector, for instance, Munoz-Gama et al., (2022) discuss its application in early anomaly detection, failure prediction, and real-time production optimization (Weijters & Ribeiro, 2011).

Other research suggests integrating process mining with industrial automation systems, as mentioned by Lugaresi et al., (2019). This integration proposes more effective supervision and control of industrial processes by complementing industrial automation processes with process mining. This includes, according to Thramboulidis, (2001), the use of sensor data to enhance the quality and efficiency of processes.

Process mining has also been employed to improve operations in the oil and gas industry, including production optimization, leak detection, and risk management (Ghasemi & Amyot, 2016). Studies such as those by Striani et al., (2022) have demonstrated how process mining can help reduce costs and enhance safety in this industry.

2.2. Process mining in finance

The application of process mining in the financial domain has gained relevance in recent years, with the potential to enhance the optimality of financial processes. Process mining has been utilized to analyze and improve operational processes in financial institutions such as banks, insurance companies, and investment management firms. Moreira et al., (2018) mention that studies have shown how process mining can identify patterns and trends, detect fraud, enhance loan process efficiency, and optimize risk management.

Business process management in financial markets, as per Jadhav et al., (2017), has served to optimize business processes related to trading in capital markets, portfolio management, and order execution. Studies such as those by Carrasquel & Lomazova, (2019) have demonstrated how process mining can improve transparency, traceability, and efficiency in financial markets.

From the perspective of fraud detection, Gao & Ye, (2010) evaluated fraud and money laundering detection in the financial sector using process mining algorithms. By analyzing

financial transaction flows, Le Khac et al., (2009) mention that suspicious patterns and anomalous behaviors indicating illicit activities can be identified.

Process mining has also been utilized for automating financial processes, credit monitoring, payment management, and system security control, according to Molnár et al., (2023). On the other hand, Werner et al., (2021) advocates the need to identify redundant or inefficient activities that impact productivity and operational costs in financial organizations such as banks.

2.3. Business Process Model and Notation

BPMN, or Business Process Model and Notation, is a standard for modeling business processes. It allows graphically representing the steps of a process, the interactions between them, and the sequence in which they occur. It uses easily understandable symbols to describe activities, events, decisions, and workflows. This facilitates communication among different stakeholders in a project and helps visualize and understand business processes clearly and consistently (Chinosi & Trombetta, 2012).

While BPMN is widely used and has many advantages, it also has some potential disadvantages. For instance, for individuals without prior experience in BPMN, it can be overwhelming initially due to the large number of symbols and rules that need to be understood. This may take time to master fully, which can delay the adoption and effective use of the notation in an organization. Although BPMN is highly versatile, there may be cases where certain processes cannot be represented easily or clearly, leading some organizations to fall into the trap of overusing BPMN or documenting unnecessary processes that overload the model.

2.4. Petri Network

A Petri network consists of two main elements, places, and transitions. Places represent states or conditions of the system, while transitions represent events or actions that can occur in the system. These places and transitions are connected by arcs, which indicate the relationship between them (Grobelna & Karatkevich, 2021).

When a transition occurs, it can consume a certain number of tokens (marks) from input places and produce a certain number of tokens in output places. Tokens are simply abstract units that represent resources, conditions, or states of the system. Petri networks are useful for modeling and analyzing concurrent systems, such as communication systems, network protocols, manufacturing systems, and software processes. They can be used to predict system behavior, identify concurrency issues, and optimize performance.

In systems with many concurrent interactions, the number of possible states can exponentially increase, known as "state explosion." This can make analysis and verification of system properties computationally expensive or even impractical. Some features of real systems, such as temporal concurrency, complex synchronization, or stochastic behavior, may be difficult to model accurately and effectively with standard Petri networks.

The way a system is represented in a Petri network can affect the interpretation and analysis of the model. Small changes in representation can have a significant impact on model behavior, requiring careful design and validation. Although there are tools and techniques for analyzing Petri networks, these may have limitations in terms of scalability, ability to handle complex models, or ability to address certain types of analysis, such as formal property verification. Despite these disadvantages, Petri networks remain a powerful tool for modeling

and analyzing concurrent and distributed systems, if they are used carefully and supplemented with other techniques and tools as needed.

2.5. Related work

Process mining is a rapidly growing tool in contemporary literature, with a focus on efficient organizational process management. While this methodology was heavily debated by researchers in the 1990s, the benefits of process mining in organizations are only now beginning to be realized. Kipping et al., (2022) conducted a qualitative-inductive study to explore how process mining can be leveraged in organizations. However, the study reveals that some processes cannot be optimized through process mining due to deviations caused by human factors in data input.

Currently, industrial organizations employ various process approaches such as the Six Sigma quality approach. This approach partially contributes to organizational performance improvement, focusing on cost reduction and innovation in the production process. Specifically, Six Sigma is designed for the production area of industrial organizations and is not applicable to administrative, financial, and market process management. Park & Kang, (2016) mention that most process management approaches include traditional interviews and process analysis, which heavily rely on observation. This conventional analysis is time-consuming and yields subjective and incomplete results without a competent system to measure improvement effects. As a tool to overcome this limitation of conventional analysis, Park & Kang, (2016) mention process mining techniques through analysis and utilization of large amounts of data.

Based on the above premise, data processing is a process management technique that helps users quickly and objectively discover processes by analyzing data and automatically visualizing real process flows in organizations.

Another methodology applied to determine the structure of organizational processes is process engineering, which stipulates rules and function constraints in organizational processes. Thus, Bala et al., (2015), address the problem of the actual structure of processes, allowing them to model the correct structure of organizational processes. However, this study does not consider Petri nets, as they consider it a poorly documented topic currently. Regardless, this paper helps visualize process-oriented processes in organizations other than industrial organizations, whose potential facilitates decision-making in organizational management.

Another interesting work is related to current information systems such as Enterprise Resource Planning and Supply Chain Management, which record events in so-called event logs. From these, process mining emerges as the evolution of Enterprise Resource Planning systems that complement Supply Chain Management, systems in determining organizational processes by indicating organizational and control structures. Currently, the academic community is researching the integration of process mining with long-language process models or generative artificial intelligence (Berti et al., 2023).

The objective of this research article is to demonstrate the applicability of process mining to model the accounting processes of an industrial organization in Colombia. The most significant aspect of this work is the main flow of the invoice handling process. The frequency of activity execution allowed visualizing process bubbles.

The case study was conducted in a liquor factory in Colombia and shows some limitations of process mining, such as certain interactions that are not visible, such as users working around the system, and some specific cases regarding privacy issues in invoices and

contracts.

3. Methodology

The present study was conducted using process mining methodology (Van der Aalst & Weijters, 2004). However, this section begins with a literature review to visualize the scope of process mining and identify relevant works related to this research. Subsequently, the methodological stages of process mining are elaborated to determine the structure of contractual and budgetary processes in the case studies. Section 3.1 presents the literature review, followed by the description of the case study in Section 3.2. Section 3.3 outlines the extraction of data in XML format from the event log for the mining algorithm, while Section 3.4 focuses on cleaning the extracted data from the Enterprise Resource Planning system known as SAP in the mentioned case study.

3.1. bibliometric analysis

To initiate this case study, the Web of Science, Scopus, and Google Scholar databases were utilized via the PoP (Publish or Perish) tool, enabling the extraction of many articles on a specific topic. Following the search using the search equation "Process mining and finance," the Bibliometrix software was employed to uncover the thematic map of research in this area and the number of annual publications (Aria & Cuccurullo, 2017).

The methodology used for the literature review is based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) method, which serves as a guide for conducting systematic reviews and meta-analyses in the field of engineering research. Given that process mining is a development based on data mining and computer science, the PRISMA method was deemed appropriate (Haddaway et al., 2022). Table 1 illustrates the methodology applied for the literature review.

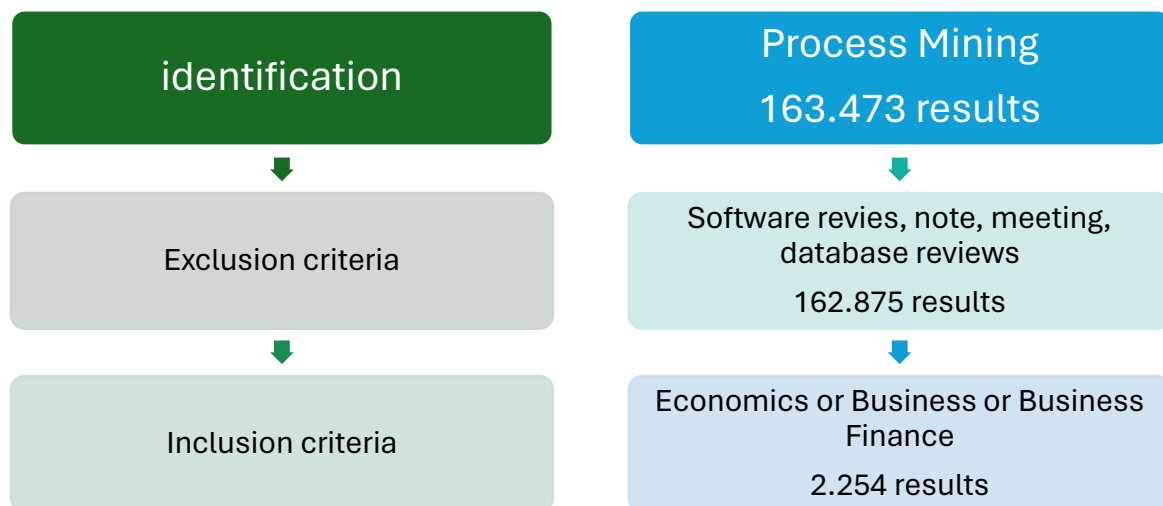


Figure 1. Bibliometric analysis

Source: Own elaboration

In Figure 1, the exclusion criteria are depicted, which were defined as articles written

in a language other than English, books, editorial opinions, and articles unrelated to the research area. The inclusion criteria included articles written in English, articles corresponding to academic events, and those published in journals. Upon applying the filter of inclusion and exclusion criteria, the number of publications reduced to 2254 articles. Subsequently, Figure 2 illustrates the word cloud representing the emerging topics in the research field.

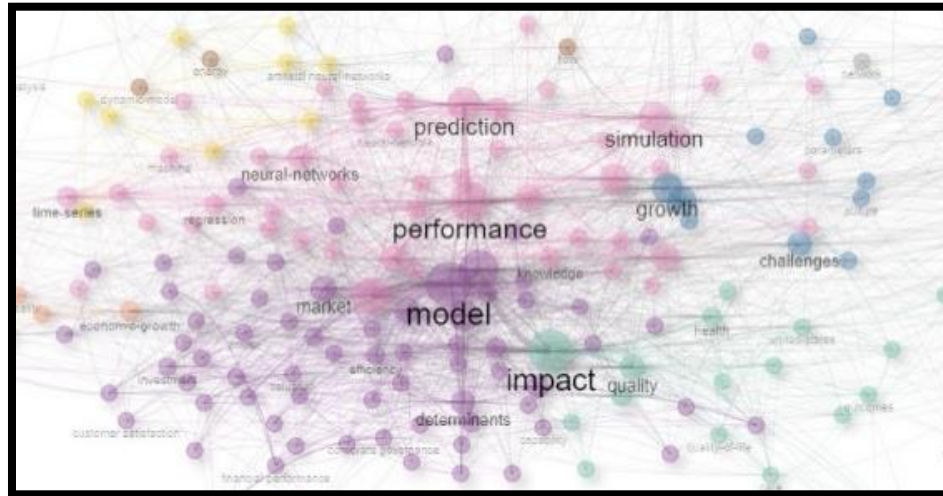


Figure 2. Bibliometric analysis

Source: Own elaboration

Figure 2 presents a thematic map that aids in highlighting the significance of the topics currently addressed. It also provides a basis for utilizing performance, simulation, and prediction as crucial elements for the present case study. In Figure 3, the thematic map showcases the main degrees of developed topics versus their degree of relevance.

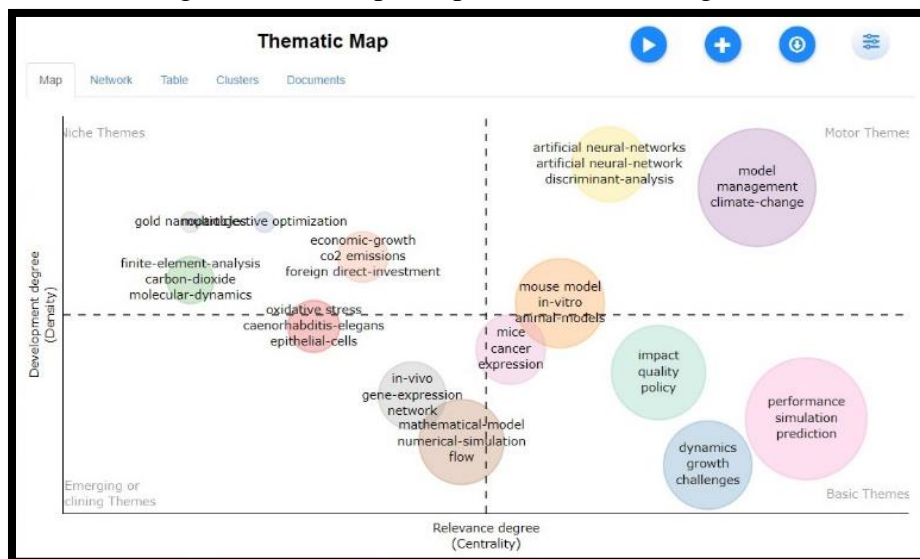


Figure 3. Thematic map of Process mining

Source: Own elaboration

In Figure 3, the most relevant research fields with the highest degree of publications are oriented towards the artificial intelligence technique known as neural networks. It is not specified whether they are recurrent or convolutional neural networks. Additionally, there is a focus on the development of management models for climate change. However, this demonstrates for the present study that an alternative to using machine learning techniques for financial process management is process mining.

In this regard, the current study presents a methodology for determining accounting and contracting processes in the case study using process mining, which aligns with previous works. The methodology is depicted in Figure 4.

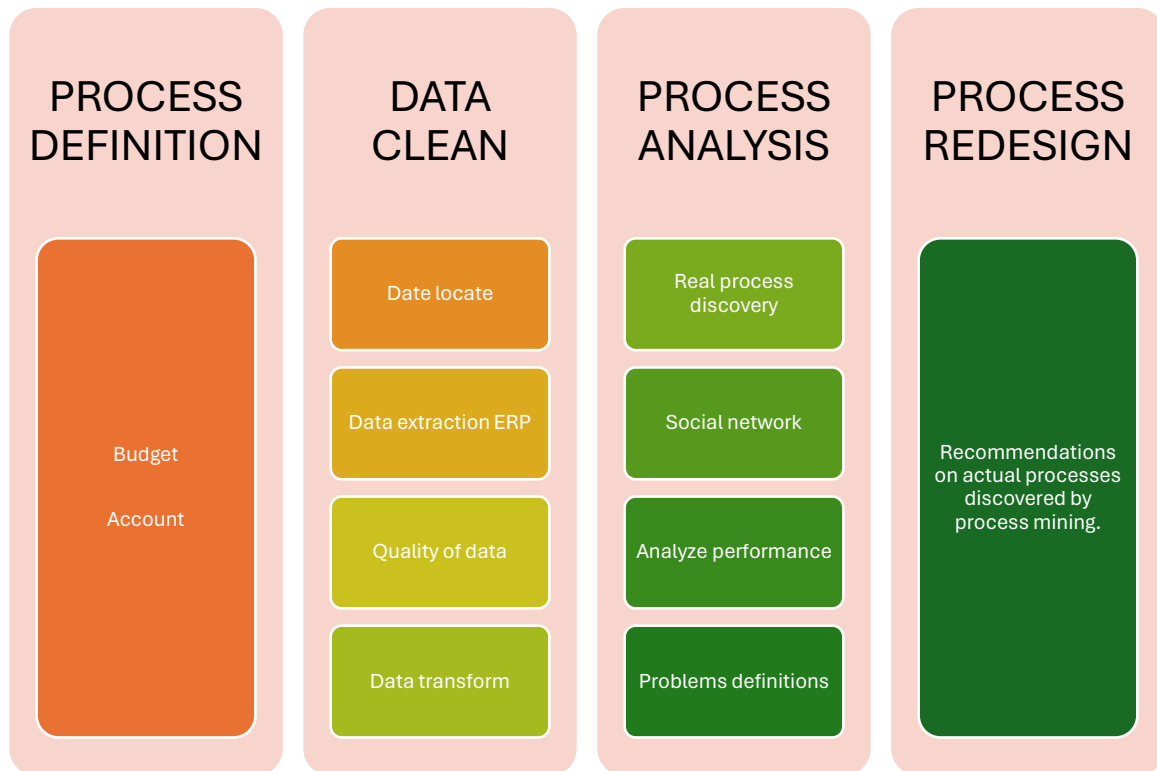


Figure 4. Proposed methodology

Source: Own elaboration

Figure 4 provides a graphical representation of the methodology applied in this case study. This methodology is limited to processes where the aim is to analyze information with event logs that include at least case identification, activity, and start and end times of the process.

Once an appropriate dataset has been agreed upon, different analysis perspectives can be identified. These may include control flow, organizational, and case data. The analysis phase is divided into basic discovery analysis and more detailed analysis of compliance and performance of the processes designed by the alpha miner algorithm.

The mentioned algorithm enables the discovery of valuable information to locate bottlenecks and visualize the loads and capacities of process stages and the resources used for it. This is evidenced in Figure 5, which is oriented towards the annual procurement plan

of the case study.

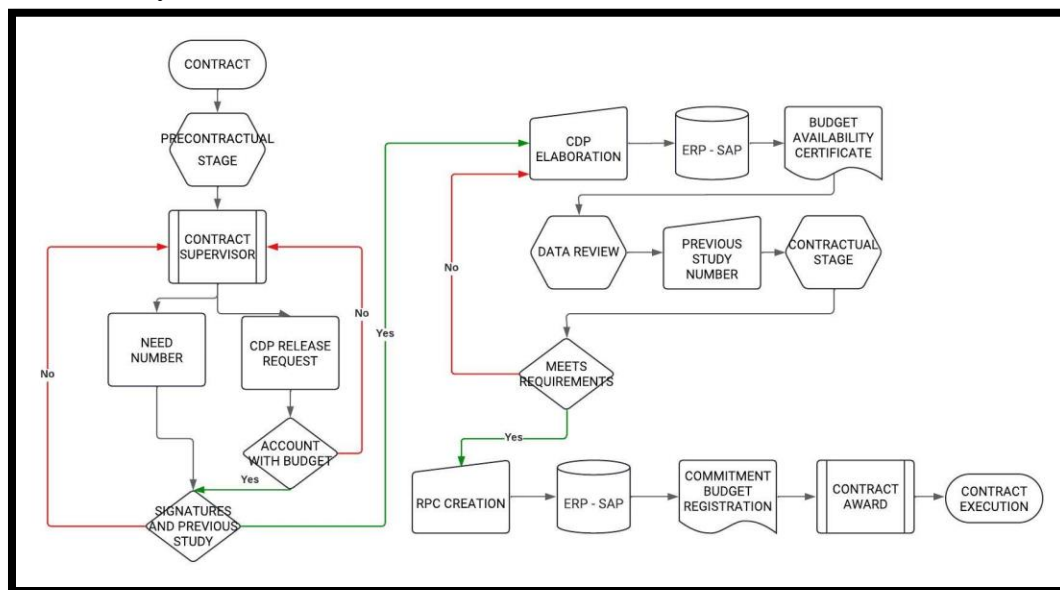


Figure 5. Flowchart of contracting structure

Source: Own elaboration

Figure 5 illustrates the data preparation process extracted from the SAP as Enterprise Resource Planning system, utilizing the primary information from the Annual Procurement Plan (APP) of the years 2021, 2022, and 2023 of the Antioquia Liquor and Spirits Factory, a State-owned Industrial and Commercial Enterprise specializing in the production of alcoholic beverages from cane, sugar, and molasses. Table 1 outlines step-by-step the methodology used, whether any software was employed as a tool, and the resulting activities.

Table 1. Data preparation

Methodology step	Tools	Activities
Data locate Data extraction	Enterprise Resource Planning SAP	Data from the SAP Enterprise Resource Planning system was utilized for information retrieval. The tables containing the required data were identified, and a report was created in transaction ZMMPUR027. Subsequently, the data was extracted in .xlsx format for visualization in Microsoft Excel.
Quality data/data clean	Microsoft Excel	A data quality analysis was conducted, focusing on identifying missing data and checking the consistency of dates. No inconsistencies were detected during this review process.
Data transform		No data transformation was required as the SAP Enterprise Resource Planning provided the information in the necessary format.

From Table 1, it is observed the version of the SAP information system, the export of data to an Excel file, and the data cleaning and transformation processes carried out on the Excel file to feed the software with the alpha miner algorithm, which allows defining the structure of the accounting and contractual processes of the case study. Next, Table 2 shows the number of cases recorded for the event log of the accounting and contractual processes of the case study.

Table 2. The Number of cases recorded

Number of register	1.899
Cases of number	1.899
Camps	Continue (YES/NOT) #. Need Version approval date Object brief requirement Accounting Account UNSPSC Code Desc. UNSPSC Type Resource (Expenditure) Post Pre Functional Area Description-Functional Area Project Desc. Project (WBS) Estimated Start Date.Start.Proc Selection Estimated Contract Duration (Day's cal) Process Duration(Qty) Process Duration(Und) Description. Modality Description Cause Total, Value Date Subscrip.

From Table 2, the variables to be analyzed can be identified. This part is crucial because, depending on the combination of events and activities, inconsistencies in the expected outcome may arise. The analysis phase is divided into basic discovery analysis and more detailed compliance and performance analysis. This stage will reveal points of interest that will require further assessment.

3.2. Study case

With the purpose of illustrating the effectiveness of process mining analyses in practical situations, a case study conducted in the alcoholic beverages industry is presented. Therefore, the sector is conducive to the application of process mining, as it encompasses a wide range of processes, focusing on production and distribution, which can significantly benefit from event log analysis. The addressed case focuses on the renowned Fabrica de Licores y Alcoholes de Antioquia located in Itagüí-Colombia. The company produces a variety of products, including liquors and hydrating beverages, distributed both nationally and internationally.

The Fabrica de Licores y Alcoholes de Antioquia is a State Industrial and Commercial Enterprise (EICE), which utilizes the SAP system as its Enterprise Resource Planning, responsible for consolidating vast amounts of data and transactions including sales, purchases, contracting, financial records, raw materials, among others.

This case study concentrates on the procurement and contracting stage and its relation to budgetary items. Procurement and contracting in an EICE have specific characteristics based on commercial code, in addition to being part of an exempted regime but subject to the disqualifications of Law 80 of 1992, which pertains to public procurement. Moreover, EICES must govern their budgets under the norms of the organic budget statute of Decree Law 111 of 1996 and Ordinance 28 of 2017. The result of the data interaction between the contracting process and budgetary items will provide inputs for a more objective understanding of bottlenecks and unnecessary reprocessing that may affect the effectiveness and efficiency in the execution of the company's processes.

3.3. Data preparation and exploration

During the data preparation and exploration stage, the SAP Enterprise Resource Planning system is utilized, whereby the necessary information is filtered using transaction ZMMPUR027 Procurement plan for follow-up. This information is then exported to an Excel file format for the years 2021, 2022, and 2023, resulting in 1899 events. The exported file is reviewed, and empty lines that could potentially lead to errors in the information analysis are removed.

Due to the vast number of variables provided by the SAP Enterprise Resource Planning system, including accounting codes, cost centers, contract supervisors, among others, the decision is made to conduct the analysis solely using data from the procurement process modality description and budgetary item.

3.4. Exploration data in ProM software

The data is entered into the ProM Lite application using the cleaned file. Figure 6 illustrates the quantity of events that occurred over the course of those three years and which

budget items had the most participation and impact on the procurement processes. In Figure 6, both the absolute and relative occurrences across the 7 contractual processes are visualized.

Log Summary		
Total number of process instances: 7		
Total number of events: 1899		
Event Name		
Event classes defined by Event Name		
All events		
Total number of classes: 26		
Class	Occurrences (absolute)	Occurrences (relative)
2-1-2-02-02-008	510	26,856%
2-4-5-02-08	401	21,116%
2-1-5-02-08	213	11,216%
2-4-5-01-03	122	6,424%
2-4-5-01-04	103	5,424%
2-1-2-02-01-004	80	4,213%
2-4-5-01-02	69	3,633%
2-1-2-02-02-009	65	3,423%
2-1-5-01-02	52	2,738%
2-1-2-02-01-003	40	2,106%
2-4-5-02-06	35	1,843%
2-3-2-01-01-003-02-05	33	1,738%
2-1-5-01-03	32	1,685%
2-1-2-01-01-003-02-05	26	1,369%
2-1-2-02-02-006	24	1,264%
2-1-5-01-04	21	1,106%
2-1-2-02-02-007	14	0,737%
2-1-2-02-01-002	12	0,632%
2-4-5-02-09	9	0,474%
2-1-5-02-06	8	0,421%
2-4-5-02-07	8	0,421%
2-3-2-02-01-004	7	0,369%
2-1-2-01-01-003-06-02	5	0,263%
2-3-2-01-01-001-03-19	5	0,263%
2-1-2-02-02-005	4	0,211%
2-1-5-02-05	1	0,053%
Start events		

Figure 6. Flowchart of contracting structure

Source: Own elaboration

Figure 6 depicts the initial report aimed at providing an early inspection of how many times a budget item was affected according to the procurement process used. Similarly, it provides a summary of events based on the contract type, offering a clearer view of how often the event occurred. Figure 7 illustrates a graphical relationship of how many events occur in each of the 7 contractual processes.

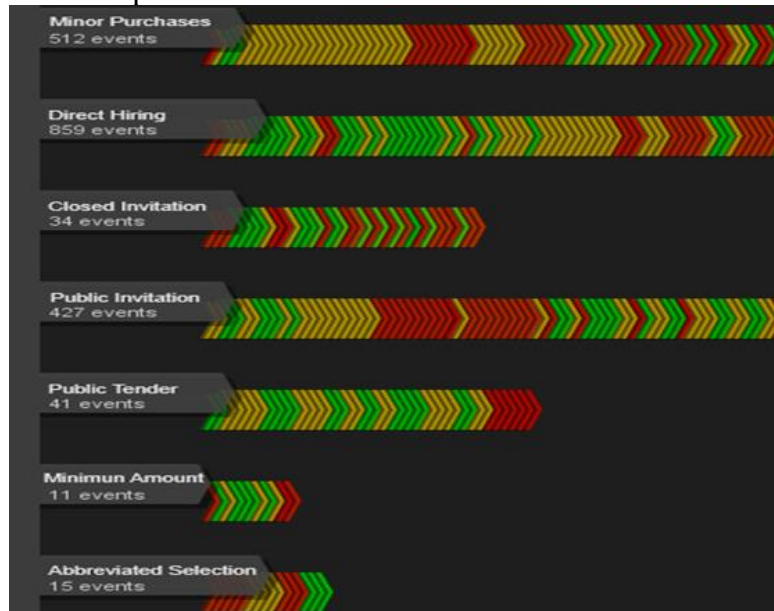


Figure 7. Register XES

Source: Own elaboration

In Figure 7, the intensity and extent of the accounting and contractual processes in the case study are observed, where yellow represents the slowest activities, green indicates the fastest flowing activities in the process, and red denotes activities that take longer to develop in the process. Subsequently, Table 3 provides the total event summary.

Table 3. Total, events analysis

Contract type	Number
Direct Contracting	859
Minor Purshaces	512
Public Invitation	427
Public Tender	41
Closed Invitation	34
Abbreviated selection	15
Minimum Amount	11
Total, Events	1899

Based on Table 3, it is observed that the process with the highest number of events is direct contracting, while the process with the fewest associated events is the minimum quantity process. This justifies the need to develop the structure of the contractual process for the case study using process mining, allowing for efficient management of activities

related to this process. The minimum quantity process is not very common in the case study due to the organization's size and its presence in the national market with its various products.

4. Results

4.1. Fuzzy model diagram

The Fuzzy model is a proposal used to analyze the different events of the variables, where the "case" column represents the description of the classification modality of the contractual and budgetary processes in the case study. The model is presented in Figure 8.

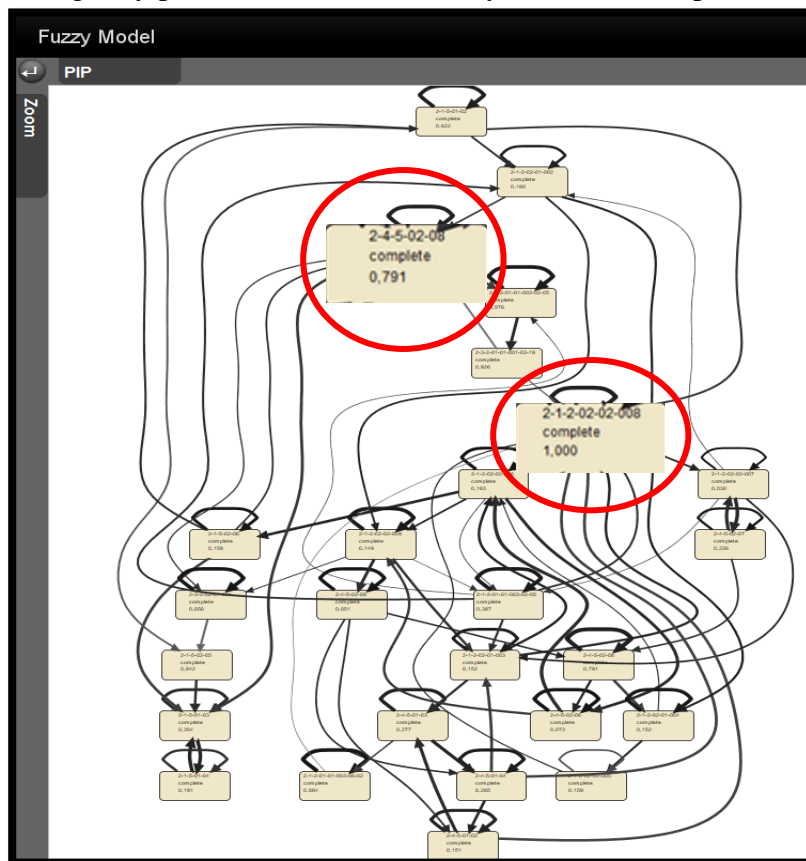


Figure 8. Fuzzy model of the contractual and budgetary processes⁵

Source: Own elaboration

The Fuzzy Model presented in Figure 8 is designed to differentiate between various categories, focusing on 2-1-2 for administrative areas and 2-4-5 for marketing, sales, and production areas. Additionally, the termination of the category represents a budgetary characteristic. This is crucial for analyzing in more detail how contracting behaves and how much is allocated to the company's expenses and costs.

It's important to note that the model lacks a starting and ending node. Through simulation, a segment of the Fuzzy model is selected to simulate the packages delivered in each process. This further confirms that the process is heavily framed within categories 2-1-2-02-02-008 and 2-4-5-02-08. Figure 9 provides a more detailed view of a portion of the

⁵ Note: This figure shows where the highest concentration of activities occurs during an event

complete Fuzzy model, pinpointing how that segment of the model performed.

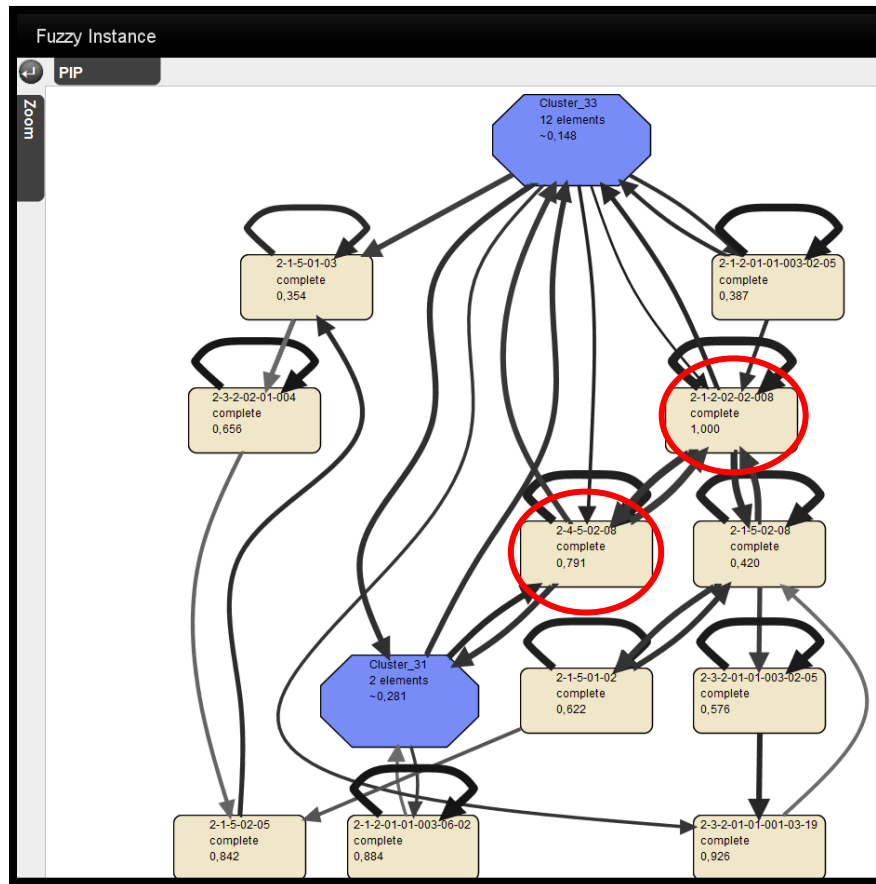


Figure 9. Fuzzy Model Instance⁶

Source: Own elaboration

Based on Figure 9, a simulation is conducted using the ProM software. This simulation illustrates how packages move through clusters and events in the Fuzzy Model, visually displaying where loops and repetitions of contracts occur based on budgetary categories. Figure 10 provides a snapshot of the Fuzzy model simulation, which sends packages according to the contracting modality. At its center, it focuses on budgetary categories with the highest volume of events or contracts.

⁶ Note: This figure depicts a snapshot of the fuzzy model, showing multiple activities passing through an event, and allows for identifying the budget items most used by contract types.

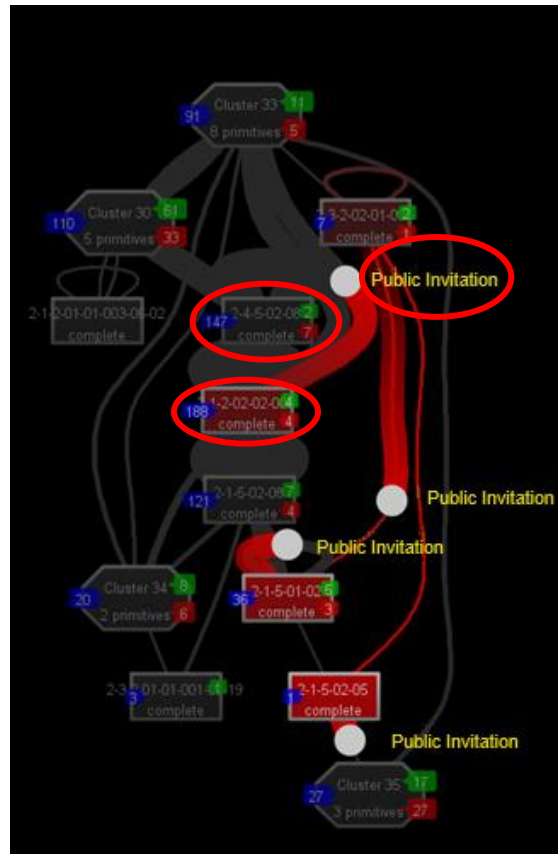


Figure 10. Fuzzy Model Simulation

Source: Own elaboration

Figure 10 indicates, as a result of the simulation, that a large number of transactions pass through budgetary categories 2-1-2-02-02-008 and category 2-4-5-02-08. These two budgetary categories interact with a higher volume of contracting modalities, suggesting that the vast majority of contracting processes are based on service procurement.

In a portion taken from the animation in Figure 10, events are represented as white dots representing different types of contracting processes and how they travel through budgetary categories according to their nature. The Fuzzy model presents several nodes, which combine different contractual events with budgetary activities. This can occur due to:

1. Some processes may change their contracting modality while using the same budgetary category.
2. Some contractual processes may change their contractual nature, requiring a change in the budgetary category.

These situations are highly specific and not the focus of this study; therefore, there is no in-depth exploration of why these scenarios occur. However, it is important to mention these variations in the outcome of the Fuzzy model, as they represent reprocessing that can lead to bottlenecks and significant delays in the contracting process.

4.2. Petri net

From the ProM Lite software, it is possible to simulate the Petri Net, which is a process representation method under the BPMN approach, allowing the identification of

events through a simple structure of logical inputs and outputs.

In Figure 11, from P12 to P21, represent the budgetary, accounting, and treasury events of the contracting process of the Fabrica de Licores y Alcoholes de Antioquia. The first limitation of the PIPE v4.3.0 program is that there is no control of events in case of having a T or bifurcation in the process; the software distributes the events evenly, which does not reflect the reality of the data provided in the contracting process. Another disadvantage is that it does not allow importing databases into the system, requiring manual input of entries.

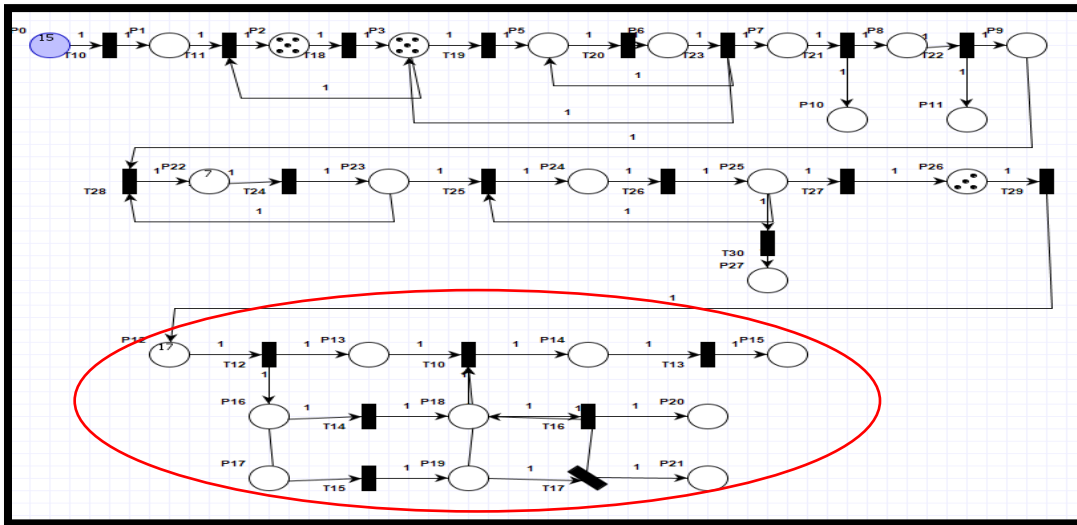


Figure 11. Petri net

Source: Own elaboration

Figure 11 identifies the absence of event control in case of having a T or bifurcation in the process. To solve this issue, the Petri Net model proceeds to distribute the events evenly, contrary to the reality of the contractual process present in the case study.

Given the aforementioned circumstance, a switch to the ProM Lite program is made, which automatically generates a Petri Net, taking into account the variables entered into the system. In this case, the events are the types of contracting processes compared with the budget items through which the contracts must pass to affect the company's accounting.

Below, in Figure 12, the Petri Net generated by the ProM program is observed.

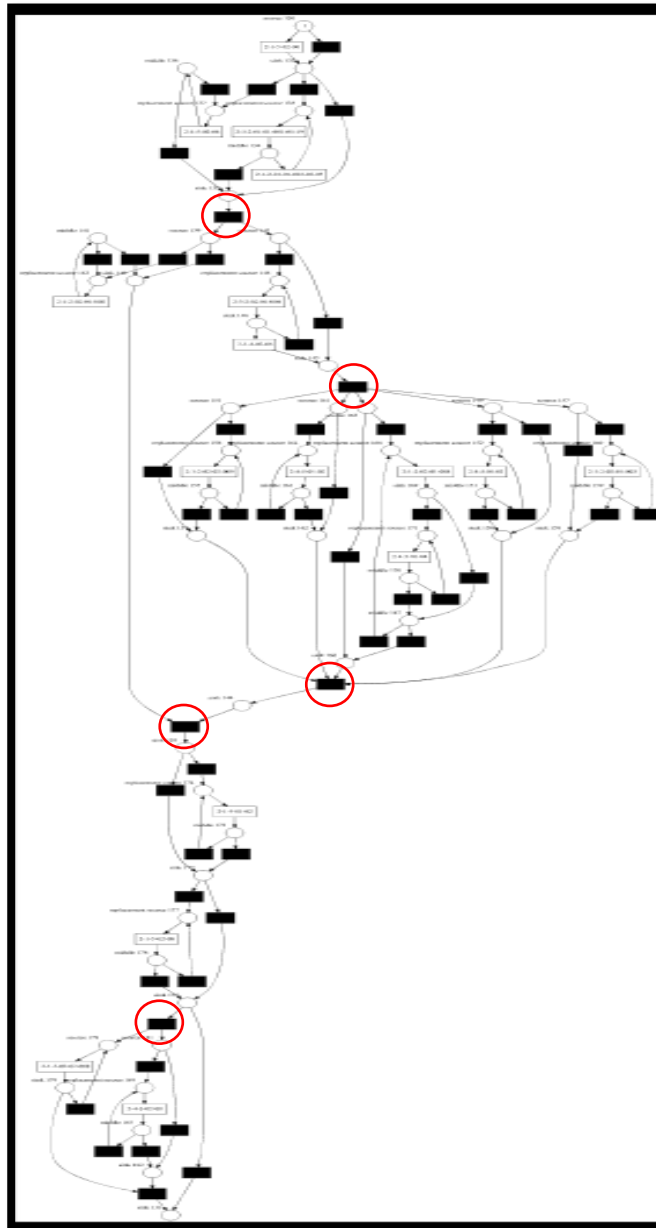


Figure 12. Petri net of Fabrica de Licores de Antioquia-Colombia's contractual and budgetary model

Source: Own elaboration

In Figure 12, the Petri diagram is observed, and the points of the contractual and budgetary processes with the highest number of accumulated activities are identified in red, coinciding with the simulation results. Next, Figure 13 presents the process tree.

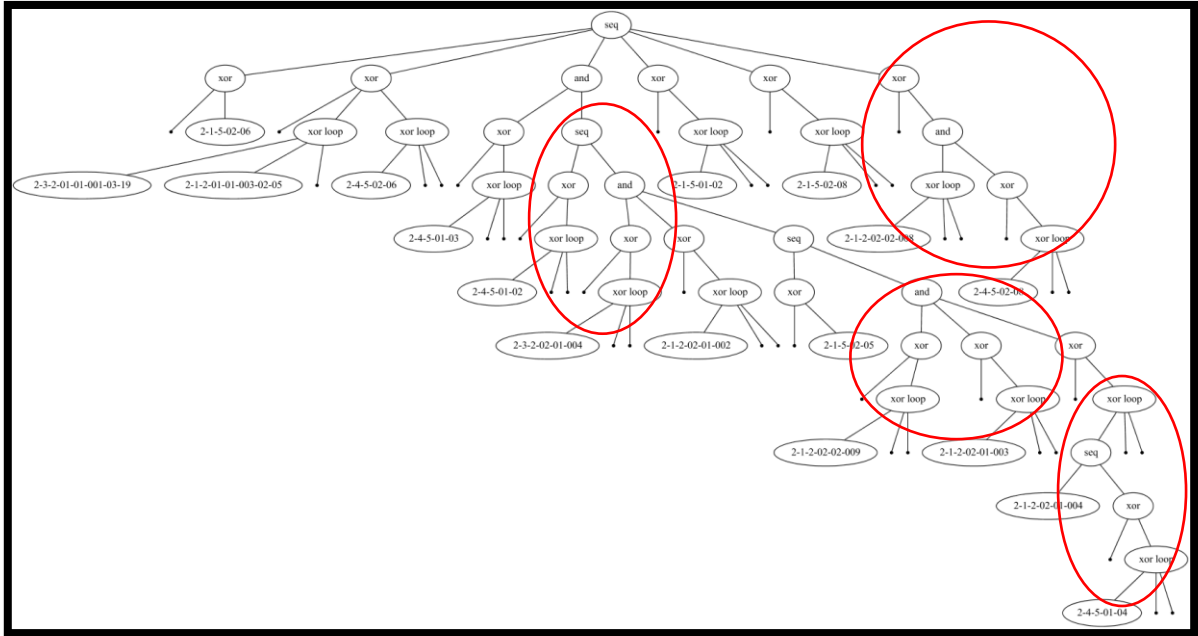


Figure 13. Contracting and budgeting process tree⁷

Source: Own elaboration

In Figure 13, the process tree is simulated, where one can identify which budget items show possible sequences of events or decisions that may occur over time. This reveals the complexity of the contracting process and the various paths an event takes to fulfill the activities. In the simulation of the process tree, many bifurcations with redundant decisions can be identified, which create bottlenecks that do not guarantee the correct execution of contracts and may increase process costs due to time increments.

An important point to highlight is the abundance of "xor" decisions, which are exclusive choices among several options, meaning that only one of them can be selected. Additionally, "xor loops" are observed, where these exclusive decisions can repeat multiple times in a loop, potentially returning to the decision point and repeating once more.

Moreover, in many of the "xor loop" decisions preceded by an "xor," they do not end up in a budgetary position, causing them to return to the decision point and repeat the process until reaching the budget item. This results in a wearisome process and elongated contracting times.

The most affected budget items are 2-1-2-02-01-004 and 2-4-5-01-04, which according to the budget catalog pertain to metallic products, machinery, and equipment. These exhibit lengthy chains of "and" decisions, which could be simultaneous activities required to progress, "seq" tasks necessary to continue to the next steps, and "xor" decisions, as mentioned earlier, which are mutually exclusive choices, allowing only one decision to proceed with the process.

5. Discussions

⁷ Note: In this figure, you can identify the possible sequences of events or decisions that may occur over time. Different types of decision chains such as "xor", "and", and "seq" are visible.

For this section, the Disco software in its Evaluation version was used, which helps to confirm the data obtained in the simulation with ProM Lite. From this perspective, it is a more statistical and graphical tool that helps generate tables to facilitate interpretation. Below, Figure 14 represents the behavior of activities concerning contractual events.

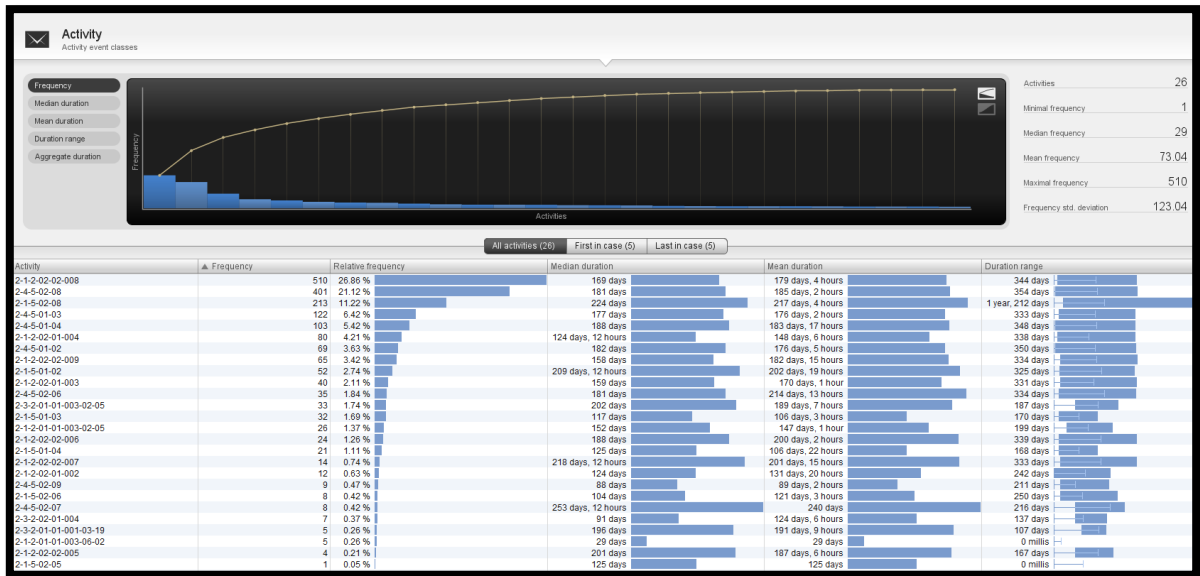


Figure 14. Performance of commitment items

Source: Own elaboration

In Figure 14, the results of the test with the Disco software are evident, which processed 1899 events from the event log. Of these, 859 were direct procurement and 512 were minor purchases. From the above information, the budget items showing the most activity are 2-1-2-02-02-008 with a frequency of 510 events, and item 2-4-5-02-08 with a frequency of 401 contractual events. These items ending in 08 belong, according to the budget classification catalog, to services provided to companies and production services for the industrial sector of Colombia, which directly relates to service provision contracts. In Figure 15, the behavior of contractual processes during the years 2021, 2022, and 2023 can be seen. It presents important data that ProM Lite does not show, allowing the identification of contract behavior over the course of the three years.

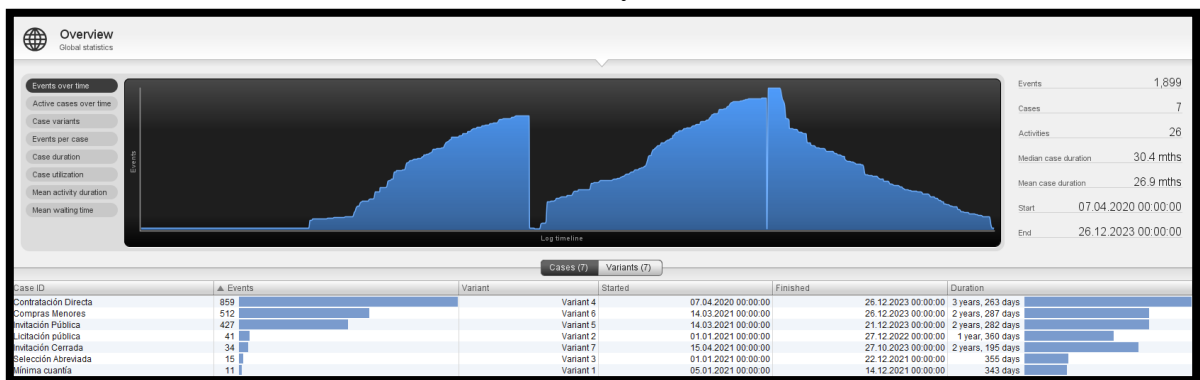


Figure 15. Activities of the contractual processes for years 2021, 2022 and 2023 for Fabrica de Licores de Antioquia-Colombia

Source: Own elaboration

In Figure 15, three peaks in the procurement processes can be clearly identified, revealing that in the year 2021, the procurement process experienced a slowdown at the beginning of the year, which can be explained by the transformation of Fabrica de Licores de Antioquia-Colombia to the new Colombian parameters of public procurement.

For the year 2022, there is an increase at the beginning of Figure 15, which is due to contracts that transition from fiscal year validity to future fiscal year validity, guaranteeing the budget in the next fiscal year and reducing the time in the procurement process.

For the year 2023, a downward effect is observed, unlike the previous years. While the majority of contracts are secured with future fiscal year validity, due to the end of the government's term in that year, most contracts cannot extend to the next fiscal year 2024 with future fiscal year validity. Consequently, they must end by December 31, 2023. Figure 16 then illustrates the budget items.

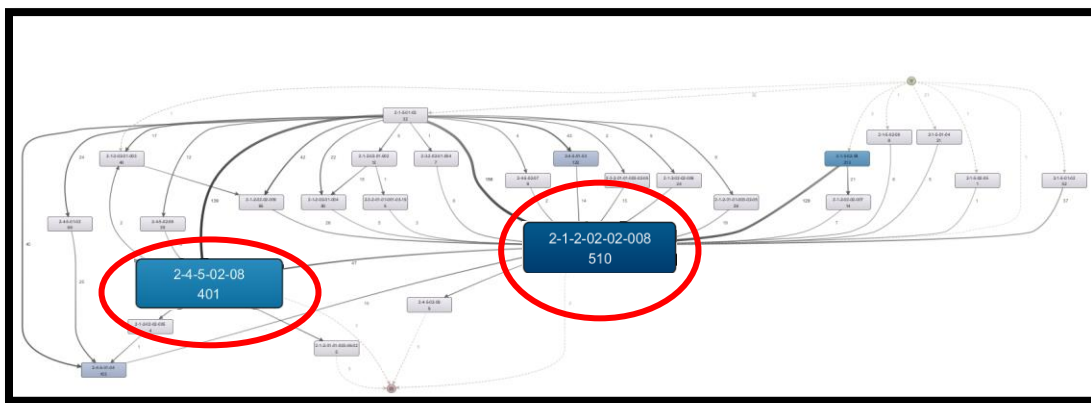


Figure 16. Frequency of budget items and contractual effects of the Fabrica de Licores de Antioquia

Source: Own elaboration

Figure 16 displays which budget items are most recurrent with the types of contractual events. This allows us to see that service processes are closely linked to the purchase of packaging materials in the liquor production process. These budget items are categorized as items 2-1-2-02-01-003 and item 2-4-5-01-03 in the Colombian budget catalog, classified as other transportable goods (excluding metallic products, machinery, and equipment). Next, Figure 17 illustrates the performance of the budget items. Figure 17 depicts the performance of the budget items.

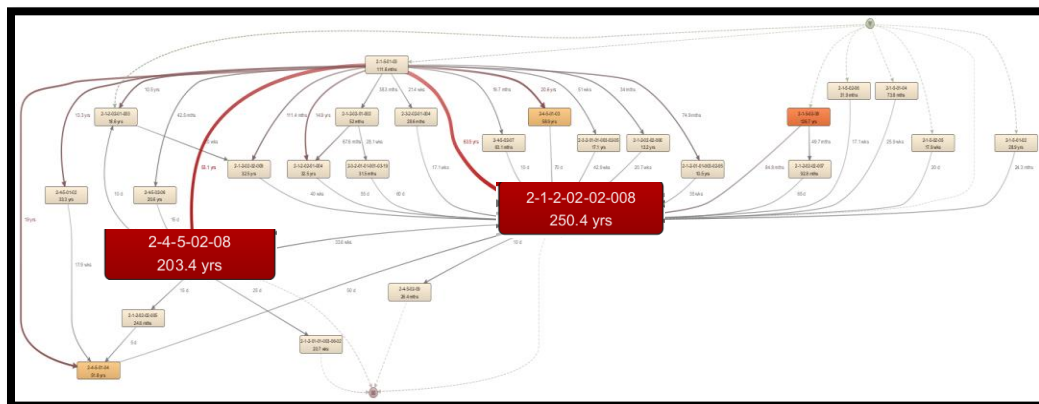


Figure 17. Performance of budget items

Source: Own elaboration

Figure 17 highlights in red the activities of the processes with the highest intensity or frequency of development, corresponding to budget items 2-1-2-02-02-008 and 2-4-5-02-08. This indicates an impact on their execution due to the type of contracting modality developed in the case study.

6. Conclusions and future research

Firstly, the results obtained from the application of these tools are highlighted, revealing critical points in the contractual process as well as bottlenecks that may generate additional costs in contracting. Secondly, the integration through different tools for process mining allows the identification of inefficiencies in the contractual and budgetary processes.

Based on the results obtained, it enables an effective and transparent description of the true contractual and budgetary process in the case study, an industrial organization. The third contribution of this research is to develop a methodology for the implementation of the alpha miner algorithm to define the structure of the contractual and budgetary processes of the case study named "Antioquia Liquor Factory" in Colombia.

An additional contribution of this research is the application of an engineering technique aimed at defining process structure focused not only on production processes but also on accounting, budgetary, and financial processes.

Limitations of this research include the application of only one case study for contractual and budgetary processes in Colombian organizations. The application of process mining in organizations requires IT infrastructure and an information system that facilitates event log data, which is the input for the alpha miner algorithm. Another limitation in this research is the use of only one mining algorithm for defining process structures; future research should evaluate the performance capabilities of other mining algorithms for defining contractual and budgetary process structures. Other future research directions could involve the incorporation of Large Language Model (LLM) with the alpha miner algorithm for defining processes in different case studies.

The construction of the Petri net model facilitates the organization of the case study to consider, in the medium term, implementing management strategies aimed at improving the provision of contractual and budgetary services from the accounting and financial areas, as the results obtained by the mining algorithm fulfilled the objective of this research to define the real processes of the accounting and budgetary areas of the case study.

The results of this study indicate that process mining is a powerful engineering tool that brings potent benefits in other fields of knowledge such as organizational management and finance, thus contributing to further research aimed at defining process structures using alternative techniques to BPMN, such as process mining applied to management areas.

The research focus of this article lies in accounting and financial planning, validating the interaction between two fundamental axes of the company, accounting, and budgetary processes versus contractual processes. Implementing process analysis methodologies, such as data mining (in this case, using the Alpha algorithm), is a highly practical tool that allows for identifying weaknesses in financial planning processes.

7. Declaration of competing interest

We hereby affirm that we have no significant competing interests, whether financial

or non-financial, professional, or personal, that could influence the impartial and comprehensive presentation of the work detailed in this manuscript.

8. Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

9. Authors contribution's

Gaviria Martinez Isaac Mauricio, contributions of paper: software ProM and written.

Beltrán Linares Yeraldine, contributions of paper: software Disco and PIPE v4.3.0 and written.

Sanchez-Obando, contributions of paper: methodology and research leader

Duque-Mendez, contributions of paper: style and validation in research

All author(s) read and approved the final manuscript.

10. Data availability statement

The authors confirm that the data supporting the findings of this study are available within the article [and/or] its supplementary materials.

11. Acknowledgements

Universidad de Manizales.

References

- Adriansyah, A., Van Dongen, B. F., & Van Der Aalst, W. M. P. (2011). Conformance checking using cost-based fitness analysis. *Proceedings - IEEE International Enterprise Distributed Object Computing Workshop, EDOC*.
<https://doi.org/10.1109/EDOC.2011.12>
- Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics, 11*(4).
<https://doi.org/10.1016/j.joi.2017.08.007>
- Bala, S., Cabanillas, C., Mendling, J., Rogge-Solti, A., & Polleres, A. (2015). Mining project-oriented business processes. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics), 9253*. https://doi.org/10.1007/978-3-319-23063-4_28
- Berti, A., Schuster, D., & van der Aalst, W. M. P. (2023). Abstractions, Scenarios, and Prompt Definitions for Process Mining with LLMs: A Case Study. *International Conference on Business Process Management, 427–439*.
- Blount, Y., Abedin, B., Vatanasakdakul, S., & Erfani, S. (2016). Integrating enterprise resource planning (SAP) in the accounting curriculum: a systematic literature review and case study. *Accounting Education, 25*(2).
<https://doi.org/10.1080/09639284.2016.1138136>
- Carrasquel, J. C., & Lomazova, I. A. (2019). Modelling and validation of trading and multi-agent systems: An approach based on process mining and petri nets. *CEUR Workshop Proceedings, 2432*.

- Chinosi, M., & Trombetta, A. (2012). BPMN: An introduction to the standard. *Computer Standards and Interfaces*, 34(1). <https://doi.org/10.1016/j.csi.2011.06.002>
- Gao, Z., & Ye, M. (2010). Journal of Money Laundering Control A framework for data mining-based anti-money laundering research A framework for data mining-based anti-money laundering research. *Journal of Money Laundering Control Journal of Money Laundering Control Iss Journal of Money Laundering Control Iss*, 10(1).
- Ghasemi, M., & Amyot, D. (2016). Process mining in healthcare: A systematised literature review. In *International Journal of Electronic Healthcare* (Vol. 9, Issue 1). <https://doi.org/10.1504/IJEH.2016.078745>
- Grobelna, I., & Karatkevich, A. (2021). Challenges in application of petri nets in manufacturing systems. In *Electronics (Switzerland)* (Vol. 10, Issue 18). <https://doi.org/10.3390/electronics10182305>
- Haddaway, N. R., Page, M. J., Pritchard, C. C., & McGuinness, L. A. (2022). PRISMA2020: An R package and Shiny app for producing PRISMA 2020-compliant flow diagrams, with interactivity for optimised digital transparency and Open Synthesis. *Campbell Systematic Reviews*, 18(2). <https://doi.org/10.1002/CL2.1230>
- Jadhav, S., He, H., & Jenkins, K. W. (2017). An academic review: applications of data mining techniques in finance industry. *International Journal of Soft Computing and Artificial Intelligence*, 4.
- Kipping, G., Djurica, D., Franzoi, S., Grisold, T., Marcus, L., Schmid, S., Brocke, J. vom, Mendling, J., & Röglinger, M. (2022). How to Leverage Process Mining in Organizations - Towards Process Mining Capabilities. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 13420 LNCS. https://doi.org/10.1007/978-3-031-16103-2_5
- Knobbout, J., van der Stappen, E., Versendaal, J., & van de Wetering, R. (2023). Supporting Learning Analytics Adoption: Evaluating the Learning Analytics Capability Model in a Real-World Setting. *Applied Sciences (Switzerland)*, 13(5). <https://doi.org/10.3390/app13053236>
- Le Khac, N. a, Markos, S., O'Neill, M., Brabazon, a, & Kechadi, M. T. (2009). An investigation into Data Mining approaches for Anti Money Laundering. *Proceedings of 2009 International Conference on Computer Engineering and Applications*, 2.
- Leemans, S. J. J., Fahland, D., & Van Der Aalst, W. M. P. (2013). Discovering block-structured process models from event logs - A constructive approach. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 7927 LNCS. https://doi.org/10.1007/978-3-642-38697-8_17
- Lugaresi, G., Zanotti, M., Tarasconi, Di., & Matta, A. (2019). Manufacturing systems mining: Generation of real-time discrete event simulation models. *Conference Proceedings - IEEE International Conference on Systems, Man and Cybernetics, 2019-October*. <https://doi.org/10.1109/SMC.2019.8914025>
- Mahendrawathi, E. R., Zayin, S. O., & Pamungkas, F. J. (2017). ERP Post Implementation Review with Process Mining: A Case of Procurement Process. *Procedia Computer Science*, 124. <https://doi.org/10.1016/j.procs.2017.12.149>
- Molnár, B., Pisoni, G., Kherbouche, M., & Zghal, Y. (2023). Blockchain-Based Business Process Management (BPM) for Finance: The Case of Credit and Claim Requests. *Smart Cities*, 6(3). <https://doi.org/10.3390/smartcities6030061>
- Moreira, C., Haven, E., Sozzo, S., & Wichert, A. (2018). Process mining with real world

- financial loan applications: Improving inference on incomplete event logs. *PLoS ONE*, 13(12). <https://doi.org/10.1371/journal.pone.0207806>
- Munoz-Gama, J., Martin, N., Fernandez-Llatas, C., Johnson, O. A., Sepúlveda, M., Helm, E., Galvez-Yanjari, V., Rojas, E., Martinez-Millana, A., Aloini, D., Amantea, I. A., Andrews, R., Arias, M., Beerepoot, I., Benevento, E., Burattin, A., Capurro, D., Carmona, J., Comuzzi, M., ... Zerbato, F. (2022). Process mining for healthcare: Characteristics and challenges. *Journal of Biomedical Informatics*, 127. <https://doi.org/10.1016/j.jbi.2022.103994>
- Park, S., & Kang, Y. S. (2016). A Study of Process Mining-based Business Process Innovation. *Procedia Computer Science*, 91. <https://doi.org/10.1016/j.procs.2016.07.066>
- Rojas, E., Munoz-Gama, J., Sepúlveda, M., & Capurro, D. (2016). Process mining in healthcare: A literature review. In *Journal of Biomedical Informatics* (Vol. 61). <https://doi.org/10.1016/j.jbi.2016.04.007>
- Rozinat, A., & van der Aalst, W. M. P. (2008). Conformance checking of processes based on monitoring real behavior. *Information Systems*, 33(1). <https://doi.org/10.1016/j.is.2007.07.001>
- Sirgmetts, M., Milani, F., Nolte, A., & Pungas, T. (2018). Designing Process Diagrams – A Framework for Making Design Choices When Visualizing Process Mining Outputs. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 11229 LNCS. https://doi.org/10.1007/978-3-030-02610-3_26
- Striani, F., Colucci, C., Corallo, A., Paiano, R., & Pascarelli, C. (2022). Process Mining in Healthcare: A Systematic Literature Review and A Case Study. *Advances in Science, Technology and Engineering Systems Journal*, 7(6). <https://doi.org/10.25046/aj070615>
- Thramboulidis, K. C. (2001). Using UML for the development of distributed industrial process measurement and control systems. *IEEE Conference on Control Applications - Proceedings*. <https://doi.org/10.1109/cca.2001.974023>
- van der Aalst, W. M. P. (2011). Process Mining: Discovery, Conformance and Enhancement of Business Processes. In *Media* (Vol. 136, Issue 2).
- van der Aalst, W. M. P., Reijers, H. A., Weijters, A. J. M. M., van Dongen, B. F., Alves de Medeiros, A. K., Song, M., & Verbeek, H. M. W. (2007). Business process mining: An industrial application. *Information Systems*, 32(5). <https://doi.org/10.1016/j.is.2006.05.003>
- Van der Aalst, W. M. P., & Weijters, A. J. M. M. (2004). Process mining: A research agenda. In *Computers in Industry* (Vol. 53, Issue 3). <https://doi.org/10.1016/j.compind.2003.10.001>
- vom Brocke, J., & Rosemann, M. (2015). Handbook on business process management 1: Introduction, methods, and information systems. In *Handbook on Business Process Management 1: Introduction, Methods, and Information Systems*. <https://doi.org/10.1007/978-3-642-45100-3>
- Weijters, A. J. M. M., & Ribeiro, J. T. S. (2011). Flexible heuristics miner (FHM). *IEEE SSCI 2011: Symposium Series on Computational Intelligence - CIDM 2011: 2011 IEEE Symposium on Computational Intelligence and Data Mining*. <https://doi.org/10.1109/CIDM.2011.5949453>
- Weijters, A. J. M. M., van der Aalst, W. M. P., & de Medeiros, A. K. A. (2006). Process Mining with the HeuristicsMiner Algorithm. In *Beta working papers*.

Werner, M., Wiese, M., & Maas, A. (2021). Embedding process mining into financial statement audits. *International Journal of Accounting Information Systems*, 41. <https://doi.org/10.1016/j.accinf.2021.100514>