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## Faculty of Business Economics

Master of Management

### **Master's thesis**

#### **Literature Review on Process Mining in Auditing**

**maryam Abshoori**

Thesis presented in fulfillment of the requirements for the degree of Master of Management, specialization Business  
Process Management

#### **SUPERVISOR :**

Prof. dr. Mieke JANS



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**2023**



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Maryam Abshoori

August 2023

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## **Abstract**

Using process mining in the field of auditing has become a dynamic way to improve audit processes, support risk assessment, and modify decision-making. This study conducts a structured literature review on the relationship between process mining and auditing. In the field of auditing, the investigation of process mining offers a paradigm change in improving transparency, effectiveness, and accuracy. The study has the potential to transform audit procedures, improve the accuracy of findings, and establish the way for a time whenever data-driven audit practices are in vogue by exploring this dynamic convergence. Using an extensive method and trustworthy resources, this study started with a review of the available research. The coding method, which included both inductive and deductive coding techniques, this diligent method allowed the extraction of essential data, allowing for a thorough investigation of the process mining landscape in auditing. The results of this study provided a spotlight on important elements of process mining in auditing. Process discovery, conformance checking, performance analysis and social network emerged as key areas of process mining methodologies in the assessment. Improved transparency, risk analysis, and the discovery of social interactions are all parts of enhanced process insights. Process mining also demonstrated its potential in fields like continuous auditing and data-driven strategies. Furthermore, the study exposed obstacles encountered in the application of process mining techniques in auditing. These challenges encompassed issues such as handling duplicate tasks, grappling with process complexity and unstructured behaviour, as well as addressing privacy and security concerns. These identified obstacles underscore the intricacies that auditors must navigate when integrating process mining into their practices. Future directions pointed to the inclusion of process mining for early detection in audits, improvements in tools, and a concentration on real-world application situations. However, the study also noted drawbacks, such as the relatively small corpus of literature on the subject, highlighting the need for additional research in this area. The study identified remarkable directions for further study in the area of auditing process mining. These directions include improving process mining tools, integrating process mining into the audit process for early issue discovery, and improving auditor skill sets to comprehend complicated environments. The report clearly emphasises the advantages of combining process mining with sophisticated analytics and security methods, but it also stresses the necessity to deal with issues like scalability, risk analysis, and control-data flow integration. These future directions offer a road map for extending the use of process mining and its influence in the auditing industry. As a conclusion, this study clarifies the relevance and significance of the intersection of process mining and auditing in modern business situations. The results highlight the effectiveness of process mining approaches in advancing auditing procedures, providing insightful information, and promoting operational excellence. The study contributes to a thorough understanding of the mutually beneficial link between process mining and auditing and sets the groundwork for future research and development.

## 1. Introduction

Process mining in auditing connects audit procedures and data analysis. Auditors employ process mining tools to visualise ongoing processes using event logs and transaction data, this builds on Jans et al. (2011) work applying process mining algorithms to event logs from a European bank, demonstrating its value in auditing. Utilising Jans et al. (2011) algorithms enhance the integration of process mining into auditing practices. As demonstrated by the work of Rvan Cruchten and Hans Weigand (2022) the adoption of process mining signifies a paradigm shift, offering auditors a dynamic toolkit that not only detects errors and fraud but also fosters a deeper understanding of organisational processes. As a solution to this problem, process mining (PM) emerged, bridging the gap between process science and data science, the latter of which usually places more emphasis on modelling than data analysis (Aalst et al., 2016). Process mining endeavours to derive insights from event logs by employing a range of tools, techniques, and approaches for the purpose of recognizing, overseeing, and enhancing real-world processes (Van der Aalst, 2012). Process mining technology proves highly adept at extracting pertinent details from established procedures within ERP systems. When an operational process occurs in real-time within an ERP system, the resultant data becomes instrumental in refining the procedural framework (Lars Reinkemeyer, 2022). Research results from Laporta et al. (2021) demonstrate a notable rise in the popularity of process mining approaches within the auditing industry, this surge can be attributed to their demonstrated potential in enhancing audit efficiency, uncovering fraudulent activities, and supplying critical data for informed decision-making. These collective findings from various years and researchers collectively underscore the transformative potential of process mining in reshaping audit practices. This literature review is guided by the following primary research question: How process mining is applied in auditing and what are the current challenges, advantages, limitations and the probable future directions of process mining in auditing? Our study offers the most recent review of the topic and classifies the available research into critical areas of concern. This literature review seeks to determine the existing knowledge and present status of process mining in auditing which has not been done before. The results of this study's thorough analysis provide insight on how Process Mining and auditing work together successfully. Our study advances both fields by exposing frequently used strategies, highlighting value enhancements, and addressing difficulties. These findings emphasise the potential for Process Mining to revolutionise auditing procedures while also enhancing the conversation with ideas that are relevant to current research areas. The study is structured as follows; Section 2. The background of process mining in auditing and related keywords of this research's topic is reviewed in this Section. 3. The methodology for the literature review, including the search approach and selection criteria, is described in this section. 4. The review's findings are presented in this section and are arranged according to the major themes found in the literature 5. Discussion and 6. Conclusion.

## **2. Background**

### **2.1. Analysing business processes**

There are numerous definitions of business processes now in use, for instance a process is defined as a "Structured, measurable set of actions designed to deliver a specific outcome for a specific client or market" is how Mohammed Amin Boukhatem (2021) defines a process. According to Thomas Davenport (1993) Processes are delineated as meticulously organised and quantified sequences of activities intended to yield a predetermined outcome tailored to a specific clientele or market segment. Process models can be likened to "cartographic representations" elucidating an organisation's operational procedures (van der Aalst, 2014). Process management is vital for organisations, providing a structured method to optimise operations by defining workflow elements and dependencies, this ensures clarity, efficiency, and alignment with strategic objectives, accountability is reinforced through ownership assignment, facilitating coordination and decision-making, insights from process management aid in adapting to market changes and fostering continuous improvement. In light of process mining, it becomes a fundamental aspect, guiding organisations towards operational excellence and innovation (Rosing et al., 2014).

#### **2.1.1. Process Mining**

Process Mining, encompassing the analysis of business process models and their execution records, has gained significant attention in recent years (Loyola-González, 2022). The field's growth is evident in the diverse aspects it covers, ranging from process discovery to conformance checking and process enhancement (Van der Aalst, 2012). In the course of processing cases, databases store crucial data about activity execution, offering insights into actual operations (Mannhardt, 2018). Collaborations with industry giants like SAP and Phillips have propelled the development of process mining techniques, offering an avenue to comprehend complex business processes (Van der Aalst, 2011). It's rooted in the analysis of execution data from corporate information systems, including WFMSs, ERP, and CRM systems (van der Aalst, 2016). Process mining bridges traditional model-based analysis and data-centric approaches like machine learning, connecting them to offer comprehensive insights (Agostinelli et al., 2020). At its core, business process mining aims to deduce process models from executed transactions, focusing on relationships of precedence and various routing constructs (Folino et al., 2009). This multifaceted domain continues to unveil opportunities for businesses to understand their operations and drive improvements.

#### **2.1.2. Event logs**

Event logs serve as the cornerstone for process mining analyses, involving the reconstruction and visualisation of event data to unveil activity patterns. This methodology systematically identifies bottlenecks, inefficiencies, and deviations within event logs, providing unbiased insights crucial for process improvement (van der Aalst et al., 2012). The versatility of process mining spans various



domains, from smart maintenance to quality management, contingent on the availability of event logs (van der Aalst, 2016). In the files of auditing, event logs offer a unique advantage. They not only encompass data provided by auditees but also encompass automatic, independent meta-data that captures behaviour, unlike conventional data relying solely on auditee input. This distinctiveness opens doors to novel analytical procedures, surpassing traditional audit tools in revealing insights (Jans et al., 2014). Process mining provides a unique chance to broaden the scope of analysed data and diversify the applied methodologies, transcending established audit conventions. This extension surpasses traditional audit practices, ushering in a revolutionary perspective on auditing methodologies (Jans et al., 2014).

### **2.1.3. Process discovery**

In the realm of process mining, a pioneering concept was introduced by Aalst et al. (2003), emphasising the extraction of insights from event logs and historical data for the purpose of visualising, analysing, and ultimately refining process flows. This groundwork laid the cornerstone for Process Discovery, a pivotal endeavour that systematically uncovers process bottlenecks, inefficiencies, and variations within organisations. In its essence, Process Discovery extracts process knowledge from available data sources, resulting in a coherent representation of the sequence and interrelation of tasks, decisions, and activities (Van der Aalst, 2011). Further amplifying the significance of process mining in auditing, Rozinat et al. (2008) showcased its capacity to unveil disparities between expected and actual process behaviours, bringing to light its relevance in the audit domain. As the application of process mining becomes more intricate, addressing complex processes and data structures necessitates the development of scalable discovery methodologies. Consequently, Process Discovery emerges not only as an intriguing research topic but also as a field with substantial real-world implications (Van der Aalst, 2022).

### **2.1.4. Conformance checking**

Due to the increasing complexity of business processes and the requirement to guarantee that they are in line with preset models, conformance checking, a crucial component of process mining, arose, its tries to examine how processes are being carried out in comparison to the expected behaviours, enabling organisations to spot deviations, inefficiencies, and non-compliance (Aalst & van Hee., 2002). They also paved the way by introducing the concept of process conformance, emphasising the necessity of evaluating process executions against formal process models. This laid the groundwork for the development of conformance checking techniques. An event log and a process model are both needed as inputs for conformance verification. Where log and model contradict, it should be made clear. There are numerous methods for conformance checking, Token-based replay and alignments are the two techniques that are employed the most frequently (Van der alast.,2011). The work of Rozinat et al. (2008) demonstrates how conformance checking can support auditing procedures by pointing up inconsistencies between expected and actual process behaviours, highlighting the importance of conformance checking in assuring the accuracy of financial information.

## 2.2. Process Mining in Auditing

The world of modern technology has been marked by increasing complexity since the very beginning of computers. Notably, the first programmable computer called Colossus, created by Maxwell Newman in 1943, played a crucial role in deciphering World War II cryptography. This highlighted the intricate nature of technology during that time (Haigh & Ceruzzi, 2021). This trend has continued to accelerate over the years, as Gordon Moore predicted in 1965 that the number of transistors on microchips would double every two years, emphasising the rapid pace of technological advancement (Valacich & Schneider, 2022). Consequently, the world of information systems is expected to experience even greater complexity in the foreseeable future. In the context of auditing, this rising complexity presents both challenges and opportunities. Brewster (2011) suggests that providing auditors with skills in systems-thinking can help them navigate the complexity of entity-level evidence, thus improving their ability to understand intricate environments. This hints at the potential of innovative training methods that align with the increasing complexity of systems. From a financial perspective, audits require a comprehensive understanding of an organisation's information function and the associated risk assessment. This includes information systems and their data, the technology that supports these systems, and the broader support structure for both information systems and technology (Romney & Steinbart, 2018). The concept of "risk management" takes on particular importance, involving the identification, evaluation, and prioritisation of potential threats, followed by strategies to mitigate their potential impact (Zerbino, 2021). At the core of financial auditing lies the definition established by the Institute of Internal Auditors (IIA), which characterises internal auditing as an objective and independent activity aimed at improving organisational operations. By rigorously assessing and enhancing risk management, control, and governance processes, internal auditing assists organisations in achieving their objectives and adding significant value to their operations (Narkchai & Fadzil, 2017). This financial perspective underscores the pivotal role of auditing in navigating the complex financial landscapes shaped by evolving technological complexities. Turning our attention to process mining, its growing importance within auditing becomes evident. Rozinat et al. (2008) showcase its effectiveness in uncovering deviations between anticipated and actual process behaviours. (Anwer Butt et al., 2023) highlight its potential in analysing intricate financial event logs, particularly within the financial services sector. Werner & Wiese (2021) delve into embedding process mining into financial statement audits, revealing a wealth of opportunity in internal auditors' event data. Additionally, (van der Aalst, 2011) acknowledges the undiscovered terrain that lies ahead. In this intricate landscape, Jans et al. (2010) foresee process mining as a catalyst for enhanced internal auditing, extracting insights from event logs within a business's information system. A year later, their study on procurement processes at a significant European financial services provider showcases the value of process mining in uncovering insights from entire populations (Jans et al., 2011). This narrative parallels the journey of Zerbino et al. (2021), who explore the realm of process mining in business management, unveiling eleven research gaps. Within healthcare, (Mike Pingel, 2021) illuminates the untapped potential of machine learning in conjunction with process mining. As the lights dim, the tale of process mining in auditing assumes

centre stage as a subject of growing interest. This story brings the pieces of earlier study together into a complex tapestry, leading to a thorough investigation that goes beyond the limits of former undertakings. The chapters of history and invention collide in our attempt to comprehend the dynamics of process mining within auditing, laying the groundwork for further investigation.

### **3. Methodology**

In order to review and analyse the subjects looked at Process mining in auditing , we used the methodology conducted by Yu et al. (2019) in our study. The approach starts with comprehending the issue and creating a review methodology, which we supported by designing the subsequent study questions.

#### **3.1. Research Questions**

In order to better comprehend the intimate link between process mining and auditing within the academic discourse, the present literature evaluation is grounded in addressing multiple study topics. Researchers set out to understand the complex interactions between process mining and auditing in the scholarly narrative. (Jans et al., 2011) examines the value of process mining approaches for internal auditors through the lens of a case study. Jans et al. (2013) make the argument for auditors to use process mining skills to reconsider auditing procedures, they do this by emphasising the benefits of process mining when applied to auditing. Laporta et al. (2021) provide a view into the future, highlighting possible avenues for integrating process mining and auditing. Through this journey, a tapestry of insights comes to light, bridging gaps and fostering conversations that expand the fields of process mining and auditing and result in a tale of transformation and promise. The following research questions were formulated to guide our investigation into prior research concerning process mining in auditing and to establish an outline of research topics within this domain. As a result, this review not only fills a gap but also generates informed discussion that benefits the fields of process mining and auditing.

**RQ1:** Which types of process mining techniques are frequently reported in auditing research?

**RQ2:** Which benefits and added value in auditing results can be attributed to process mining use?

**RQ3:** which difficulties and obstacles have been found in implementing process mining in auditing?

**RQ4:** which future directions are provided in the literature for process mining's implementation to auditing?

### 3.2. Literature Search

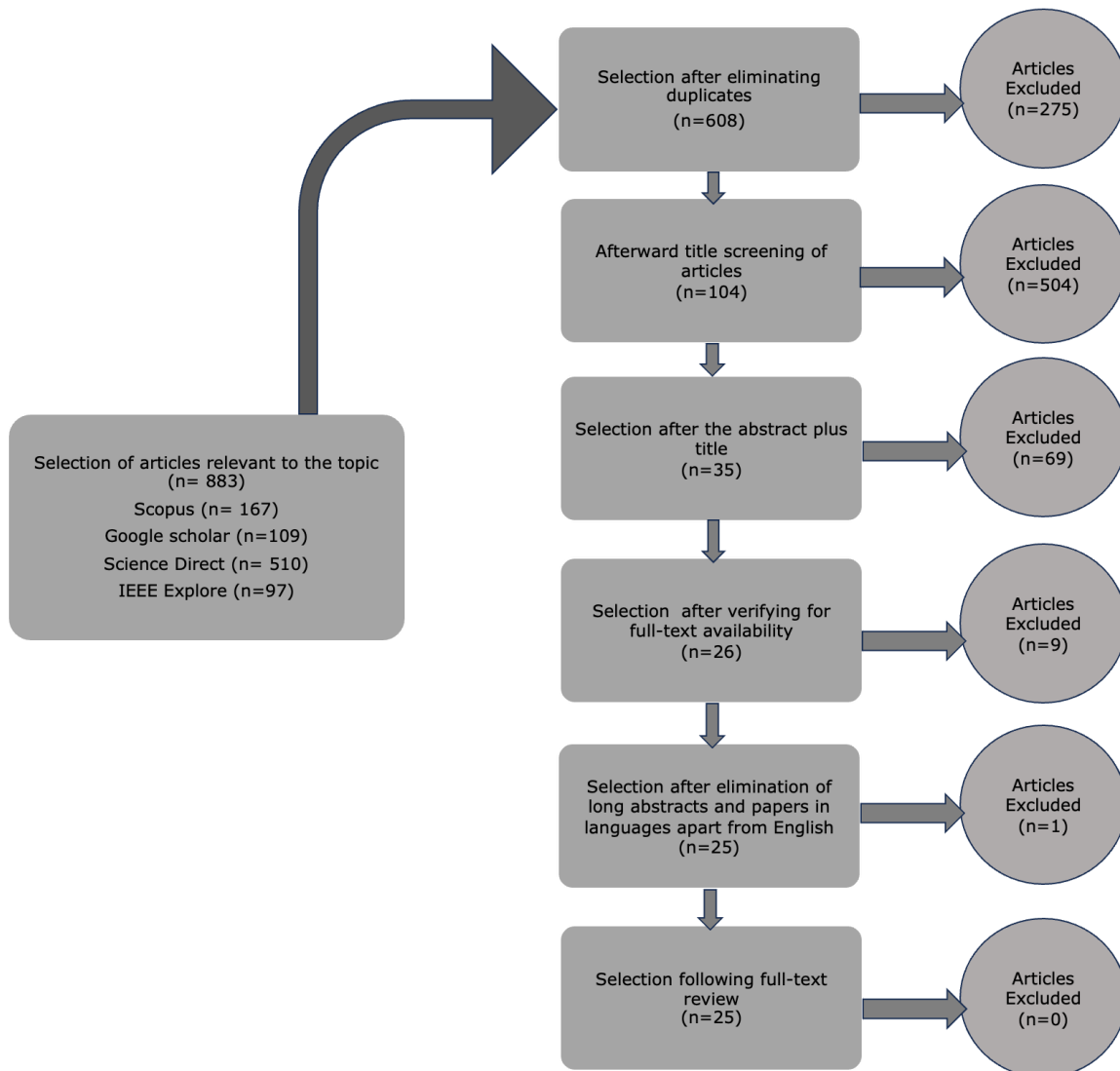


Figure 1. Methodology of paper selection

Our investigation began with search for articles in the following databases; including science direct, IEEE Xplore, Scopus, and Google Scholar. Without mandating a precise start date for the literature search, the review process took into account studies published until the year 2023.

Research criteria are built upon following search terms: ("process mining" OR "Process discovery" AND "event\*" AND "log\*" AND "Auditing") that could occur in title, abstract or keywords. We combined "process mining" with "process discovery" using the logical OR because some studies used the latter term as opposed to the former. We also used the asterisk (\*) symbol as a wildcard to represent different variations of the terms, such as event logs and events are logged, to assure full coverage. We screened the research papers by first checking their title (stage 1). Subsequently, we checked the abstract (stage 2) and the full body of text (stage 3).divided the screening process into three stages, starting with the paper title and moving on to the title and abstract and then the whole text. Only the papers that fulfil all criteria within one stage were moved to the next screening stage. if there was insufficient data to decide whether to include or

exclude a paper, it A manuscript was moved to the next following stage. if there was insufficient data to decide whether to include or exclude it based on Table 1 and 2.

A summary of our report strategy and the number of publications included and excluded at each stage are shown in Figure 1. The initial database search produced 883 results, including 510 papers from Science direct, 97 from IEEE Xplore, 109 From google scholar and 167 from Scopus. After eliminating duplicates, we checked the papers' eligibility.

### 3.3. Inclusion and Exclusion Criteria

The criteria for screening articles were developed in this step, including the prerequisites for inclusion and disqualification. Exclusion criteria (EC) refer to the removal of articles that do not fulfil particular criteria, whilst inclusion criteria (IC) refer to the selection of papers that satisfy the established requirements. Table 1 lists the criteria used to decide which articles to include. The exclusion criteria were used to weed out papers that didn't adhere to certain parameters. Papers that weren't in the English language and as you can see in table 2, the paper cannot be accessible electronically, among other things. Additionally, articles that emphasised auditing through techniques other than process mining were deemed off-topic and were excluded. Studies, those where a piece of writing is either a poster, a one-pager, or an executive summary were also excluded.

<b>Inclusion Criteria</b>	<b>Description</b>
IC 1	Articles that are readily available online and accessible
IC 2	Publications online until 2023
IC 3	Articles from conferences and journals

Table 1. Inclusion criteria

<b>Exclusion Criteria</b>	<b>Description</b>
EC 1	Process mining in auditing is not the paper's main area of interest
EC 2	A language other than English was used to write the essay.
EC 3	The paper cannot be accessed electronically.
EC 4	The paper is an extension of a conference paper that was published in a journal.
EC 5	The piece of writing is either a poster, a one-pager, or an executive summary.

Table 2. Exclusion criteria

### 3.4. Coding Scheme

We used both inductive as well as deductive coding strategies in our coding system to obtain pertinent information from the literature based on (Fereday et al., 2006) and (Crabtree & Miller, 1992) adapted from Crabtree & Miller (1999). Inductive coding facilitated the emergence of patterns and themes organically from the text, while deductive coding enabled the application of predefined categories to the data, ensuring a comprehensive exploration of the research landscape (Fereday et al., 2006).

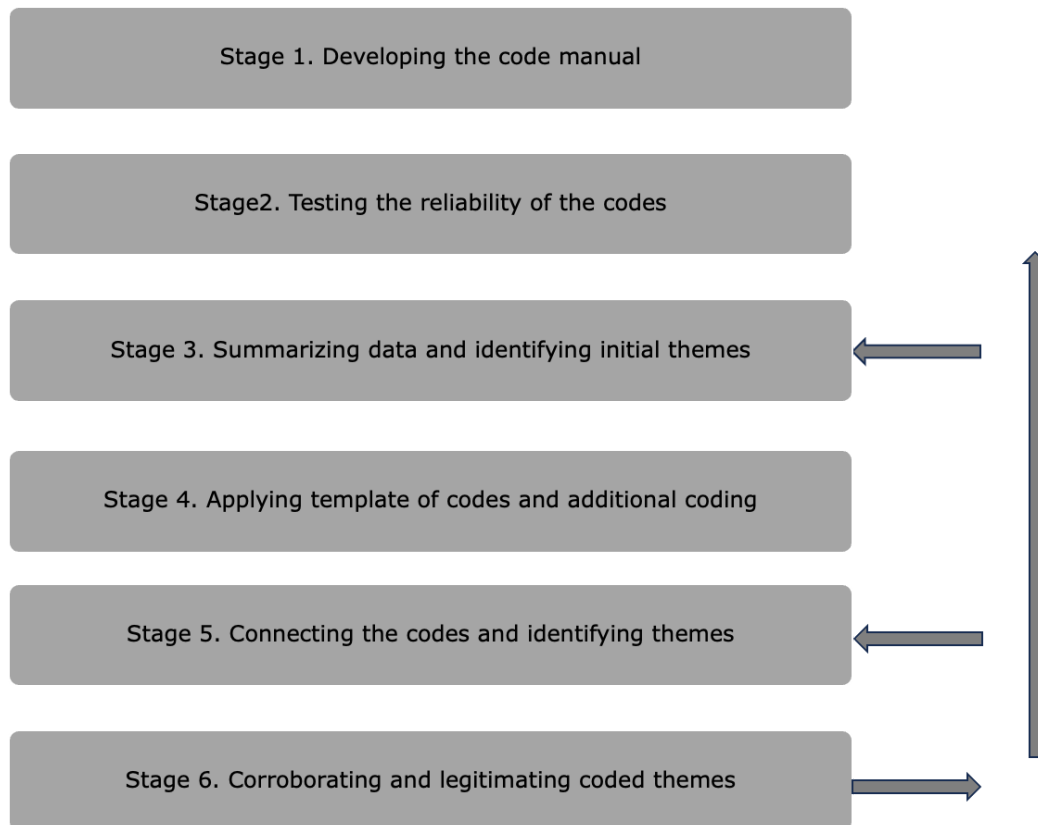


Figure 2. Diagrammatic representation of the stages undertaken to code the data analysis with mixed approach (deductive and inductive) adapted from Crabtree & Miller (1999).

We follow the guideline that has been presented by (Fereday et al., 2006). The researchers employed thematic analysis with a mixed approach of deductive and inductive coding to generate themes from participants' discussions on performance feedback and its influence on their self-assessment of nursing competence. We applied the deductive coding technique, which employs predefined codes, to extract details about the research topic, types of process mining's techniques, benefits and added value in auditing results, difficulties and obstacles, and future directions. Table 3 contains our defined set of codes based on our research questions and their descriptions.

Row	Code	Code name	Description
1	PM-T	Types of process mining techniques	The type of process mining technique has been the core subject of the research study. Possible values: process discovery, conformance checking.
2	A-VA	Advantages and added value in auditing results	Focuses on the advantages of using process mining in auditing, such as higher efficiency, improved insights into process bottlenecks, and more accuracy in finding deviations.
3	A-D	Difficulties and obstacles	The difficulties encountered when adopting process mining, such as data quality problems and complicated processes.
4	FD	Future directions	Examines possible directions for growth and development in implementation of process mining in auditing. Topics like incorporating artificial intelligence might be covered.

Table 3. Coding Scheme (Code name and Description)

## 4. Result

The findings of our literature review are presented in this section. First, we provide an overview of reviewed papers (section 4.1.). Afterward, we present a detailed analysis of the various process mining techniques (section 4.2.). A detailed study is done on the advantages and value of process mining in the context of auditing in (section 4.3.) and at the end the challenges and obstacles linked to the adoption and use of process mining techniques in the field of auditing are addressed in detail (section 4.4.). Future directions of the study (section 4.5.)

### 4.1. Overview of the reviewed papers

A total of 25 research articles were found to be crucial in addressing the questions raised by the study. To further emphasise the visual impact of the final selection of our evaluated papers, the selected research articles included in this review are completely shown in Figure 3 based on their citations.

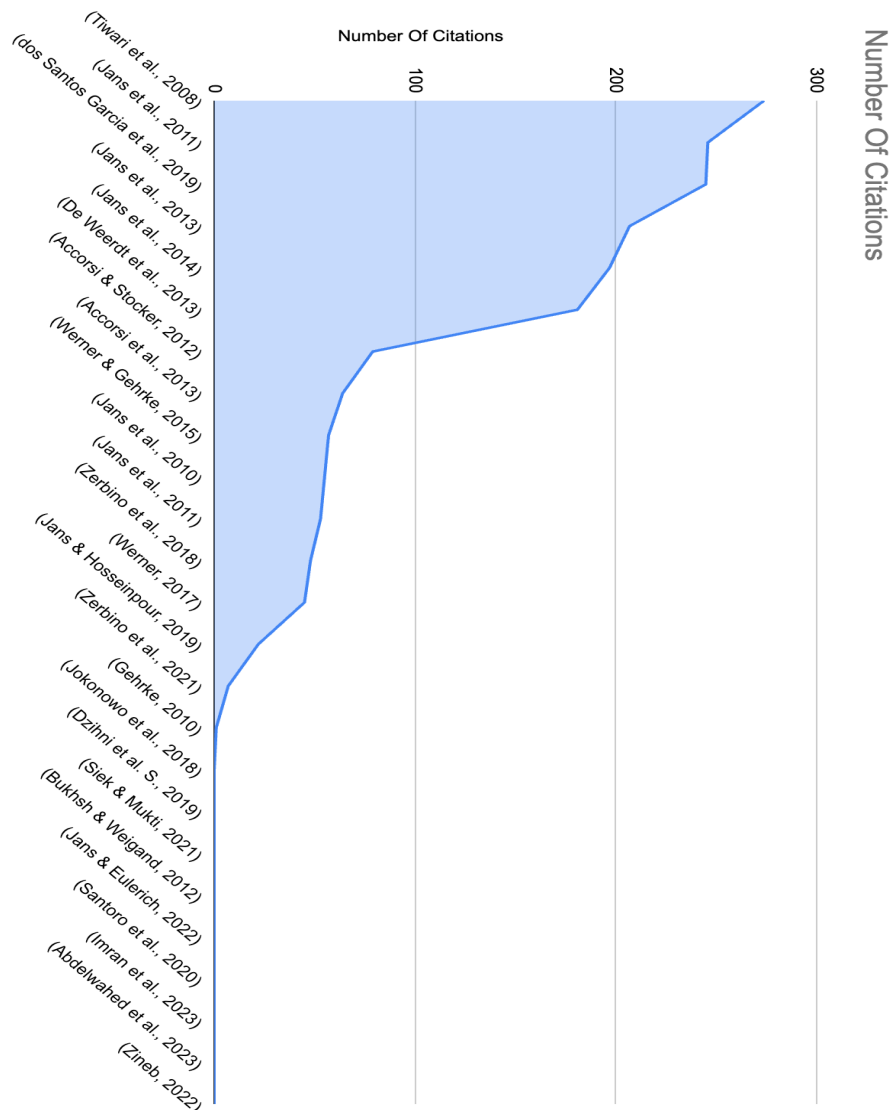


Figure 3. Overview of the final reviewed papers



## **4.2. Types of process mining techniques (PM-T Code)**

This section presents a detailed analysis of the various process mining techniques employed in the context of auditing research. As elucidated by Aalst et al. (2012), process mining is categorised into three distinct techniques: process discovery, process conformance, and process enhancement. There are many different strategies used in the field of process mining in auditing that provide insightful data into corporate processes. According to Jans et al. (2013), Process Discovery supports the extraction of process models from event logs, revealing the complexity of operational workflows and empowering auditors to increase process transparency. Gehrke (2010) elaborates the procedure of comparing actual event data to established process models, a crucial instrument in determining compliance and conformity, in the area of conformance checking. The basis for process mining analysis is event log extraction, as described by Jans et al. (2013), which gathers information from numerous sources to shed light on real process executions. (Zerbino et al., 2018) exploration of performance analysis focuses on measuring resource utilisation and process efficiency. According to Jans et al. (2013), process enhancement gives auditors the ability to optimise processes by locating inefficiencies. The use of social network analysis, as described by Jans et al. (2014), provides insight into how process participants collaborate. Role Analysis looks into role-based access and duties, as explained by Jans et al. (2011). Root Cause Analysis, championed by Zerbino et al. (2018), unearths the root causes of inefficiencies. As part of this review, we categorised the identified process mining research articles into distinct types of techniques, highlighting their applications and relevance in auditing in table 4. We additionally offered an overview of process mining techniques. Figure 4 shows the frequency of each technology based on the number of authors who mentioned or applied it.

<b>(PM-T Code)</b>		
<b>References</b>	<b>Types of process mining's techniques</b>	<b>Description</b>
(Tiwari et al., 2008) (Jans et al., 2011) (Dos Santos Garcia et al., 2019) (Jans et al., 2013) (Jans et al., 2014) (De Weerd et al., 2013) (Accorsi et al., 2013) (Werner & Gehrke, 2015) (Jans et al., 2010) (Zerbino et al., 2018) (Jans & Hosseinpour, 2019) (Zerbino et al., 2021) (Gehrke, 2010) (Jokonowo et al., 2018) (Jans & Eulerich, 2022) (Santoro et al., 2020) (Imran et al., 2023) (Abdelwahed et al., 2023) (Zineb, 2022)	Process Discovery	Process discovery involves extracting process models directly from event log data, enabling auditors to visualise and understand the underlying business processes. It helps auditors identify process variations, bottlenecks, and inefficiencies, enhancing process transparency and aiding in process improvement.
(Jans et al., 2013) (Accorsi & Stocker, 2012) (Jans et al., 2010) (Jans & Hosseinpour, 2019) (Zerbino et al., 2021) (Siek & Mukti, 2021) (Jans & Eulerich, 2022) (Santoro et al., 2020) (Abdelwahed et al., 2023)	Conformance Checking	Conformance checking compares the observed event data against the expected process model to identify compliance deviations and assess process conformance. It allows auditors to verify whether actual process execution adheres to predefined process models or regulatory standards.
(Gehrke, 2010) (Jokonowo et al., 2018) (Dzihni et al. S., 2019) (Siek & Mukti, 2021) (Bukhsh & Weigand, 2012)	Event Log Extraction	Event log extraction involves collecting and compiling event data from various sources within an organisation's information systems. It provides the foundation for process mining analysis, enabling auditors to analyse actual process executions.

(Jans et al., 2013) (Jans et al., 2010) (Zerbino et al., 2021) (Santoro et al., 2020) (Abdelwahed et al., 2023)	Performance Analysis	Performance analysis focuses on analysing process data to evaluate process efficiency, throughput times, and resource utilisation. It helps auditors identify performance bottlenecks and opportunities for process optimization.
(Zerbino et al., 2021) (Jans & Eulerich, 2022) (Imran et al., 2023)	Process Enhancement	Process enhancement uses process mining insights to improve business processes. Auditors can identify process inefficiencies and redesign workflows to enhance process performance and effectiveness.
(Jans et al., 2013) (Jans et al., 2014) (Jans et al., 2010) (Jans et al., 2011) (Santoro et al., 2020)	Social Network Analysis	Social network analysis involves analysing social relationships among individuals involved in the processes. It helps auditors understand communication patterns and collaboration structures within the organisation.
(Jans et al., 2014) (Jans et al., 2011)	Role Analysis	Role analysis identifies roles and responsibilities of individuals within the business processes. It aids auditors in understanding role-based access and potential segregation of duties concerns.
(Jans et al., 2014) (Jans et al., 2011)	Attribute Analysis	Attribute analysis focuses on analysing attributes or data elements associated with process events. It enables auditors to gain insights into the characteristics of process executions and assess data quality.
(Jans et al., 2013) (Jans et al., 2010)	Decision Mining and Verification	Decision mining involves extracting decision rules or decision points from event data. It helps auditors understand decision-making processes and assess decision compliance.
(De Weerd et al., 2013)	Feedback Loop with Business Experts	The feedback loop involves engaging business experts to validate and enrich process mining results. It ensures the accuracy and relevance of process insights.
(Jans & Eulerich, 2022) (Abdelwahed et al., 2023)	Root Cause Analysis	Root cause analysis aims to identify the underlying causes of process inefficiencies or non-compliance. It enables auditors to address the root issues contributing to process problems.
(Zerbino et al., 2018)	Model Enrichment	Model enrichment involves improving process models based on additional insights from process mining. It helps auditors create more accurate and representative process models.

(Zerbino et al., 2018)	Control Flow Model Construction	Control flow model construction focuses on building visual representations of process flows, aiding auditors in understanding process sequences and dependencies.
(Gehrke, 2010)	Process Visualisation	Process visualisation uses graphical representations to depict process flows and patterns, facilitating auditors' understanding of complex processes.
(De Weerd et al., 2013)	Data Preparation and Exploration	Data preparation involves preprocessing event log data to ensure its suitability for process mining analysis. Data exploration helps auditors gain initial insights into process data and its characteristics.
(Santoro et al., 2020)	Resource Analysis	Resource analysis focuses on assessing resource utilisation in processes, such as human and machine resources. It helps auditors identify resource bottlenecks and opportunities for resource optimization.

Table 4. Type Of Process Mining's Techniques

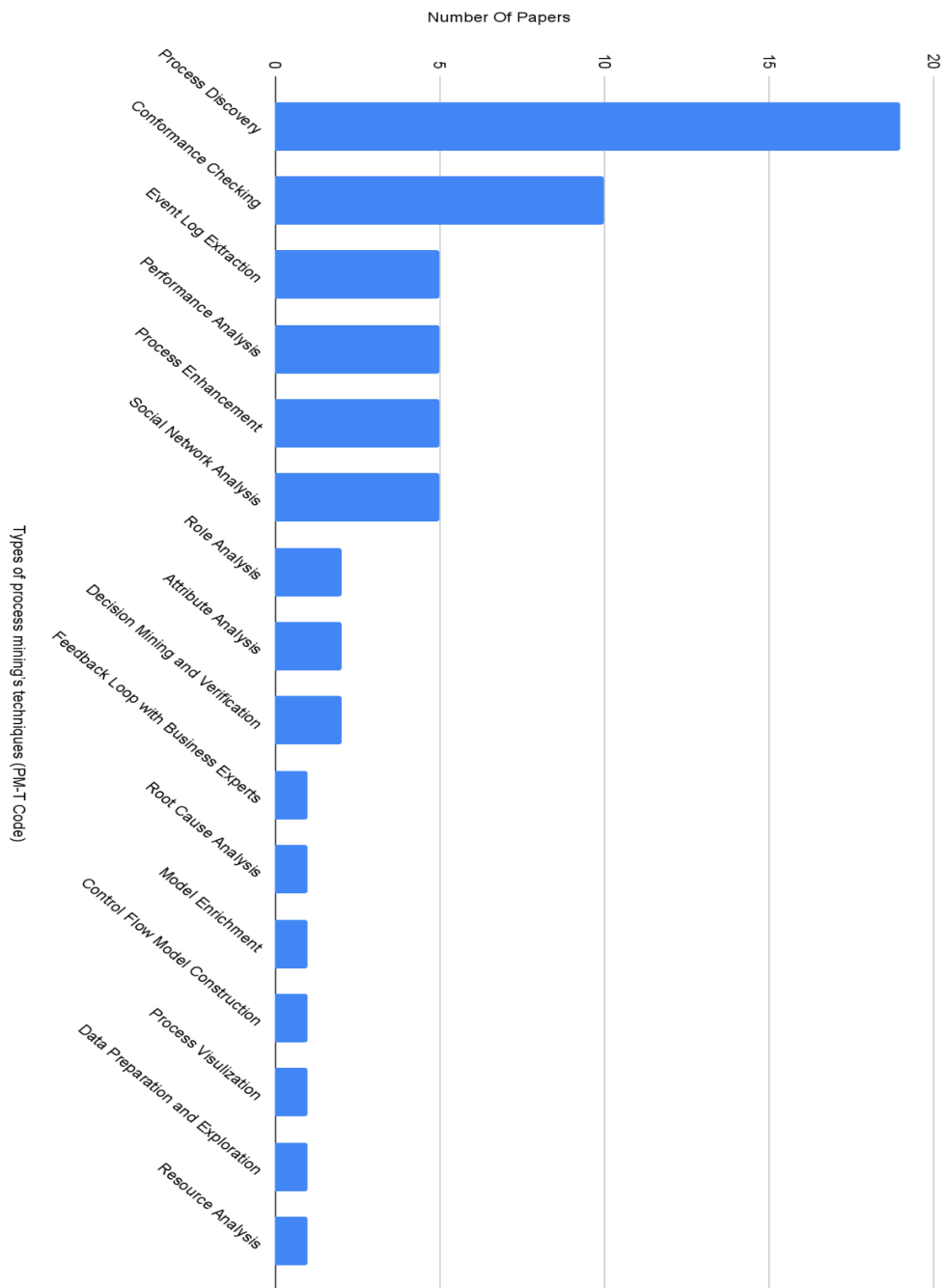


Figure 4. Types Of Process Mining's Techniques

#### 4.3. A detailed analysis of the various process mining added value in auditing (A-VA Code)

The benefits and value offered by process mining in the context of auditing are thoroughly explored in this section. In this review, we examine the cited research publications in detail to clarify the main benefits that process mining approaches in auditing procedures offer. The incorporation of process mining approaches into the field of auditing has produced a range of

significant contributions, according to a thorough analysis of numerous research. Studies by Werner & Gehrke (2015) and Dos Santos Garcia et al. (2019) specifically draw attention to how process mining produces improved insights, including greater process transparency, efficient risk assessment, discovery of social links, and the use of rich information from event logs. Furthermore, as explained by Accorsi & Stocker (2012), Jans et al. (2010), Zerbino et al. (2018), Dzhini et al. S. (2019), and Siek & Mukti (2021), audits have grown much more efficient and effective. These studies highlight how process mining offers automation support, accurate process model construction, greater effectiveness, and increased efficiency. The works of Dzhini et al. S. (2019) and Jans et al. (2013) highlight process mining's strength in verifying compliance, boosting security audits, automating security audits, and detecting fraud in terms of process compliance and evidence-based auditing. Table 5 presents an overview of different categories advantages and added value of process mining in auditing results and additionally in figure 5 we present the frequency of different added values of process mining in auditing results.

<b>Advantages and added value of process mining in auditing results (A-VA Code)</b>		
<b>References</b>	<b>Categories</b>	<b>Sub categories and Description</b>
(Jans et al., 2013) (Werner & Gehrke, 2015) (Jans et al., 2011) (Jans et al., 2014) (Dos Santos Garcia et al., 2019) (Bukhsh & Weigand, 2012) (Imran et al., 2023)	<b>Enhanced Process Insights</b>	<ul style="list-style-type: none"> <li>- <b>Improved Process Transparency:</b> Process mining provides auditors with a clear view of complex business processes, enabling a deeper understanding of process flows and deviations.</li> <li>- <b>Effective Risk Assessment:</b> Process mining facilitates risk assessment by identifying potential risks, non-compliance instances, and controlling weaknesses within processes.</li> <li>- <b>Identification of Social Relationships:</b> Process mining uncovers social relationships among individuals involved in processes, enhancing auditors' understanding of communication patterns.</li> <li>- <b>Rich Information from Event Logs:</b> The data from event logs enriches the scope of analysis, providing auditors with additional context beyond auditee-entered data.</li> <li>- <b>Comprehensive Analysis of Entire Population:</b> Process mining allows auditors to analyse the entire population of process data, enabling more accurate and reliable audit conclusions.</li> </ul>
(Dos Santos Garcia et al., 2019) (De Weerd et al., 2013) (Werner & Gehrke, 2015)	<b>Efficiency and Effectiveness</b>	<ul style="list-style-type: none"> <li>- <b>Increased Efficiency:</b> Process mining streamlines audit procedures, leading to more efficient and effective audits.</li> <li>- <b>Automation Support:</b> Process mining provides automation capabilities, reducing manual effort and improving audit efficiency.</li> <li>- <b>Precise Process Models:</b> Process mining enables the</li> </ul>

(Gehrke, 2010)		creation of precise process models, aiding auditors in identifying inefficiencies and improving process performance. - <b>Improved Effectiveness:</b> Process mining revolutionises auditing practices by uncovering valuable insights and detecting anomalies.
(Accorsi & Stocker, 2012) (Jans et al., 2010) (Zerbino et al., 2018) (Dzihni et al. S., 2019) (Siek & Mukti, 2021)	<b>Process Compliance and Evidence-Based Auditing</b>	- <b>Providing Powerful Tools for Compliance Checking:</b> Process mining assists auditors in verifying process compliance against predefined models or standards. - <b>Improved Security Audit:</b> Process mining efficiently analyses security aspects in business processes, supporting security audit efforts. - <b>Automating Security Audits:</b> Process mining automates real-time security auditing, enhancing the detection of security-related issues. - <b>Uncover Fraud:</b> Process mining aids in detecting frauds and anomalies within business processes.
(Dzihni et al. S., 2019)	<b>Continuous Auditing</b>	Process mining supports continuous auditing, enabling auditors to monitor processes on an ongoing basis. Real-Life Application and Value Demonstration: Process mining showcases its value in real-life auditing applications, enhancing audit quality and assurance.
(Jans et al., 2013)	<b>Improved Process Visualisation</b>	Process mining uses graphical representations to depict process flows, aiding auditors' understanding of complex processes.
(Zineb, 2022)	<b>Data-Driven Auditing</b>	Process mining facilitates data-driven auditing by providing evidence-based insights for auditors to base their conclusions on.
(Gehrke, 2010)	<b>Efficiency and Cost Savings</b>	Process mining leads to more efficient audits, resulting in cost savings for audit engagements.
(Jans et al., 2013) (Jokonowo et al., 2018)	<b>Transparency and Risk Identification</b>	Process mining enhances process transparency, facilitating the identification of bottlenecks and supporting effective auditing processes.
(Jans & Eulerich, 2022)	<b>Integration with Advanced Analytics</b>	Process mining integrates with advanced analytics, enhancing its capabilities for auditing complex financial processes.
(Jans et al., 2010)	<b>Cross-Department Insights</b>	Process mining provides insights that transcend departmental boundaries, contributing to a more comprehensive audit approach.

(Jans et al., 2013)	<b>Transparent and Objective Audit</b>	Process mining ensures transparency and objectivity in reproducing audit findings, leading to more reliable outcomes.
(Jans et al., 2014)	<b>Full Population-Based Audit</b>	Process mining enables auditors to conduct audits on the entire population of process data, increasing audit accuracy and coverage.
(Jans et al., 2010) (Werner, 2017)	<b>Improvement of Audit Efficiency</b>	Process mining improves audit efficiency, optimising audit efforts and resources.
(Jans et al., 2011) (Zineb, 2022)	<b>Efficiency of Internal Control Audits</b>	Process mining improves the efficiency of auditing internal controls, enabling auditors to identify weaknesses effectively.
(Jans et al., 2013)	<b>Increased Transparency</b>	Process mining increases transparency by providing auditors with a clear view of processes, enhancing audit understanding.

Table 5. Advantages and added value of process mining in auditing results



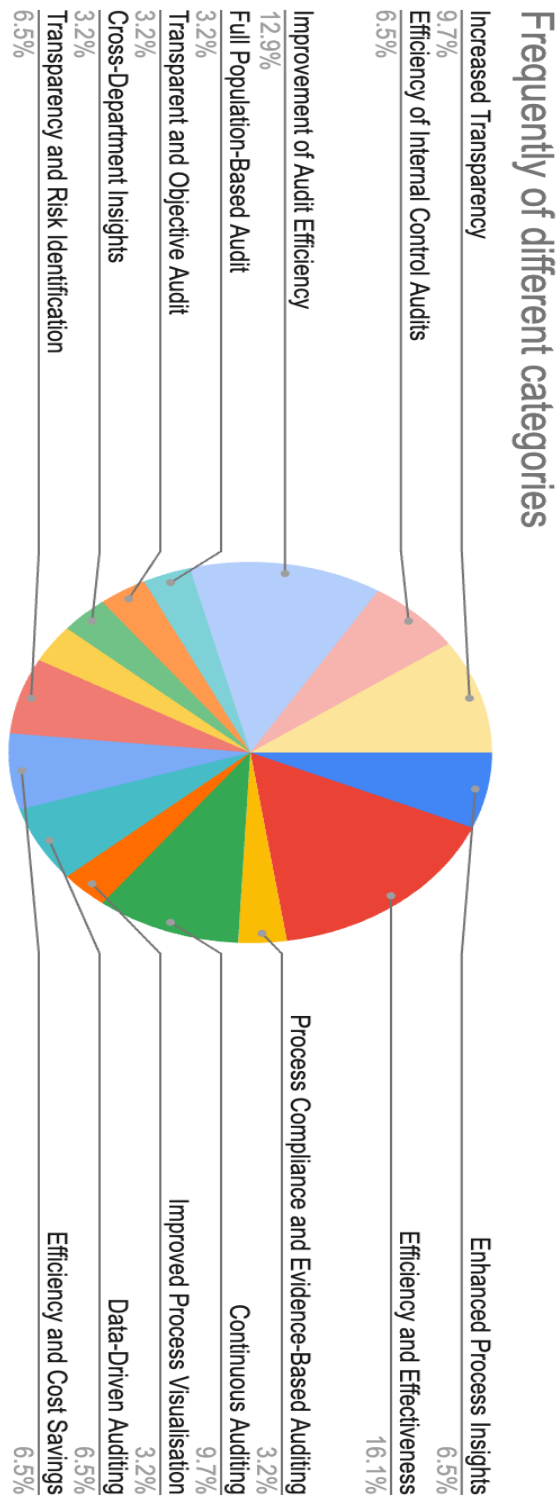


Figure 5. Frequently of different categories of added value by using process mining in auditing.

#### 4.4. Difficulties and obstacles (A-D Code)

This section critically analyses the challenges and obstacles related to the adoption and application of process mining techniques in the field of auditing. Although process mining has many advantages, it might be difficult to integrate into auditing procedures. In order to identify and

analyse the common challenges experienced by auditors when using process mining tools and methodologies, we look into the corpus of research publications for this review. Duplication of tasks, as underscored by Tiwari et al. (2008) and Dos Santos Garcia et al. (2019), introduces complexity and ambiguity in process understanding. Dealing with unstructured behaviour, noted by De Weerd et al. (2013) and Jokonowo et al. (2018), along with the intricacies of process complexity, as addressed by Accorsi et al. (2013) and Zerbino et al. (2018), emerges as a recurrent obstacle in effective process mining application. Privacy and security concerns, as highlighted by Dos Santos Garcia et al. (2019) and Accorsi et al. (2013), further underscore the need for careful consideration of data handling practices. The difficulties are further accentuated by challenges associated with data quality and availability, a concern noted by Werner & Gehrke (2015), Jans et al. (2011), Zerbino et al. (2018), and Imran et al. (2023). The lack of generalisation and the potential influence of outliers, as indicated by De Weerd et al. (2013), Zerbino et al. (2018), Jokonowo et al. (2018), Jans & Eulerich (2022), and Santoro et al. (2020), shape the landscape of process mining with a lens of caution. Complex process environments and tool limitations, a facet highlighted by Accorsi et al. (2013) and Zerbino et al. (2018), further compound the intricacies faced by auditors. By highlighting these limitations in table 6 and figure 6, we hope to give readers a thorough grasp of the difficulties involved and encourage further exploration of alternative answers and tactics to improve the successful application of process mining in auditing.

<b>Difficulties and Obstacles of using process mining in auditing results (A-D Code)</b>		
<b>References</b>	<b>Categories</b>	<b>Description</b>
(Tiwari et al., 2008)	Duplicate Tasks and Mining Perspectives	Repeating tasks, need for varied viewpoints in process mining
(Dos Santos Garcia et al., 2019) (De Weerd et al., 2013) (Jokonowo et al., 2018) (Bukhsh & Weigand, 2012) (Jans & Eulerich, 2022)	Process Complexity and Unstructured Behaviour	The intricate nature of processes, unpredictable behaviours, and incorporating data-flow information from logs are obstacles in process mining
(Dos Santos Garcia et al., 2019) (Accorsi et al., 2013) (Zerbino et al., 2018) (Jokonowo et al., 2018) (Bukhsh & Weigand, 2012) (Jans & Eulerich, 2022) (Santoro et al., 2020)	Privacy and Security Concerns	Ensuring privacy and data security, as well as integrating process mining into the audit landscape, present challenges.
(Dos Santos Garcia et al.,	Data Quality and Availability	Ensuring the quality and availability of

2019) (Accorsi et al., 2013)		data, along with addressing inaccuracies, are hurdles in process mining.
(Werner & Gehrke, 2015) (Jans et al., 2011) (Zerbino et al., 2018) (Imran et al., 2023)	Lack of Generalization and Outliers	Challenges encompass generalisation difficulties, managing outliers, and moving beyond sole reliance on input data
(De Weerd et al., 2013) (Zerbino et al., 2018) (Jokonowo et al., 2018) (Jans & Eulerich, 2022) (Santoro et al., 2020)	Complex Process Environments and Tool Limitations	Managing complex process scenarios and addressing limitations in available tools pose challenge
(Accorsi et al., 2013) (Zerbino et al., 2018)	Interpretation Challenges and Process Maturity	Interpreting outcomes accurately, assessing process maturity, and addressing bias in representation and algorithms are obstacles.
(Imran et al., 2023)	Handling Noise and Anomalies	Dealing with irrelevant data, anomalies, and complexity in process data is a key challenge.
(Imran et al., 2023)	Human Judgment and Limited Adoption	depending on human judgement, low adoption rates, and the necessity for automation tools present challenges.

Table 6. Difficulties and Obstacles of using process mining in auditing

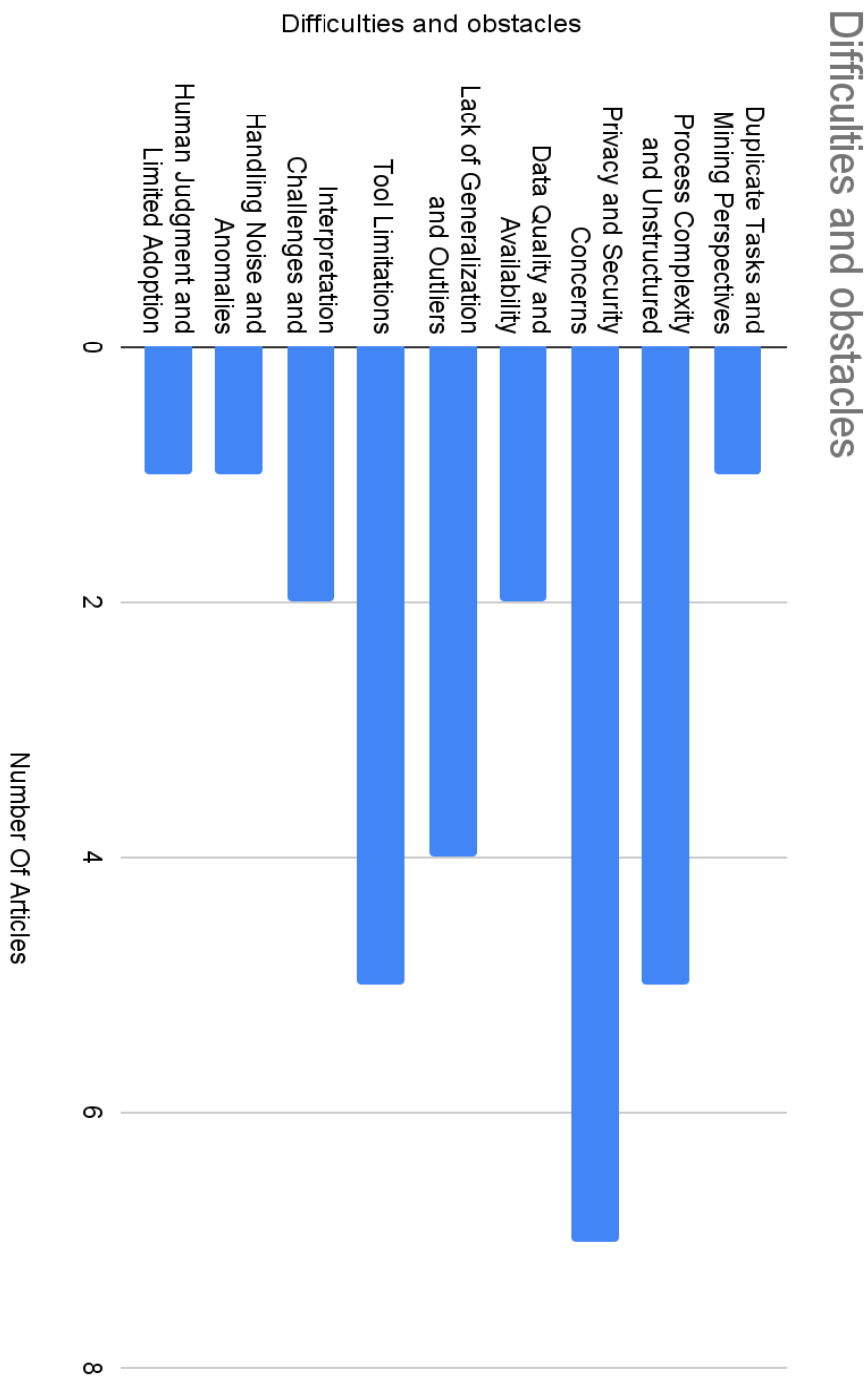


Figure 6. An overview on difficulties and Obstacles of using process mining in auditing

#### 4.5. Future Directions (FD Code)

In this section, we investigated the promising future directions of process mining in the field of auditing. We examined the selected research publications to find new patterns, ground-breaking approaches, and untapped potential that offer hope for the development of process mining in auditing in the future. Dos Santos Garcia et al. (2019) and Werner & Gehrke (2015) foresee the

integration of process mining as a means to bolster early detection of fraud and anomalies, thus enhancing the decision-making processes of audits. Accorsi & Stocker (2012) and Zerbino et al. (2018) advocate for the refinement of process mining tools to ensure their efficacy in practical auditing scenarios. This iterative improvement journey is underscored by Accorsi & Stocker (2012), Dos Santos Garcia et al. (2019), and Jans & Eulerich (2022), who emphasise the importance of nurturing auditors' skills to tackle intricate auditing landscapes. Convergence with advanced analytics and security strategies, as envisaged by Accorsi & Stocker (2012) and Accorsi et al. (2013), is poised to shape a more comprehensive and secure auditing ecosystem. Scalability, risk assessment, and control-data flow integration, addressed by Zerbino et al. (2018), set the stage for specialised techniques to surmount complexity. Zerbino et al. (2018) also underline the transformative potential of process mining in elevating audit practices. The future also encompasses advancements in online auditing and metrics, according to Jokonowo et al. (2018), and the exploration of privacy preservation, continuous auditing, and data-driven strategies as proposed by Dos Santos Garcia et al. (2019), De Weerd et al. (2013), Accorsi et al. (2013), and Abdelwahed et al. (2023). Notably, Jans et al. (2011) spotlight the integration of real-time process mining with advanced analytics as a pivotal avenue for future progress. The aspiration to fortify audit validity and refine process improvement techniques, emphasised by Abdelwahed et al. (2023), underscores the commitment to responsible growth in this domain. The integration of process mining and auditing is poised to usher in a new era of effectiveness, accuracy, and transformative insights as these paths develop. With the aid of this section, we seek to elicit discussion, guide further investigation, and clear the way for the transformational integration of process mining into auditing methods.

<b>Future directions (FD Code)</b>		
<b>References</b>	<b>Categories</b>	<b>Description</b>
(Dos Santos Garcia et al., 2019) (Werner & Gehrke, 2015) (Jans et al., 2010) (Santoro et al., 2020)	Integration of Process Mining into Audit Process for Early Detection	The future involves incorporating process mining into audits to identify fraud and issues earlier in the process, providing practical decision-making insights.
(Accorsi & Stocker, 2012) (Werner & Gehrke, 2015) (Jans et al., 2010) (Jans et al., 2011) (Imran et al., 2023)	Improvement of Process Mining Tools	Efforts are focused on enhancing the effectiveness of process mining tools
(Zerbino et al., 2018)	Advancing Auditors' Skill Sets through Process Mining	Research aims to help auditors gain skills for understanding complex environments and enhancing performance.

(Dos Santos Garcia et al., 2019) (Accorsi & Stocker, 2012) (Jans & Eulerich, 2022)	Integration with Advanced Analytics and Security Techniques	The combination of process mining with advanced analytics and security methods is a potential area of exploration.
(Accorsi & Stocker, 2012) (Accorsi et al., 2013)	Scalability, Risk Analysis, and Control-Data Flow Integration	Challenges such as scalability, risk analysis, and integration of control-data flow are addressed through specialised techniques.
(Zerbino et al., 2018)	Enhancing Auditing Practises through Process Mining	Research aims to leverage process mining techniques to enhance auditing practices and contribute to the field's development.
(Zerbino et al., 2018)	Advancements in Online Auditing and Metrics	The future involves progress in online auditing and the development of improved metrics for process analysis.
(Jokonowo et al., 2018)	Privacy, Continuous Auditing, Data-Driven Approaches	Areas of exploration include privacy considerations, continuous auditing, and data-driven approaches.
(Dos Santos Garcia et al., 2019) (De Weerd et al., 2013) (Accorsi et al., 2013) (Abdelwahed et al., 2023)	Real-time Process Mining and Advanced Analytics Integration	The integration of real-time process mining with advanced analytics holds potential for future advancements.
(Jans et al., 2011)	Focus on Application Scenarios and Process Optimization	Research aims to concentrate on practical application scenarios and optimising processes.
(Werner & Gehrke, 2015)	Ensuring Validity of Event Logs and Process Improvement Techniques	Future research addresses the reliability of event logs and develops process improvement techniques tailored for process mining-based audits.
(Abdelwahed et al., 2023)	Privacy-Preserving Techniques and Continuous Improvement	Exploration includes techniques for preserving privacy and continuous improvement strategies.

Table 7. Future direction of process mining in auditing

## Number Of Papers

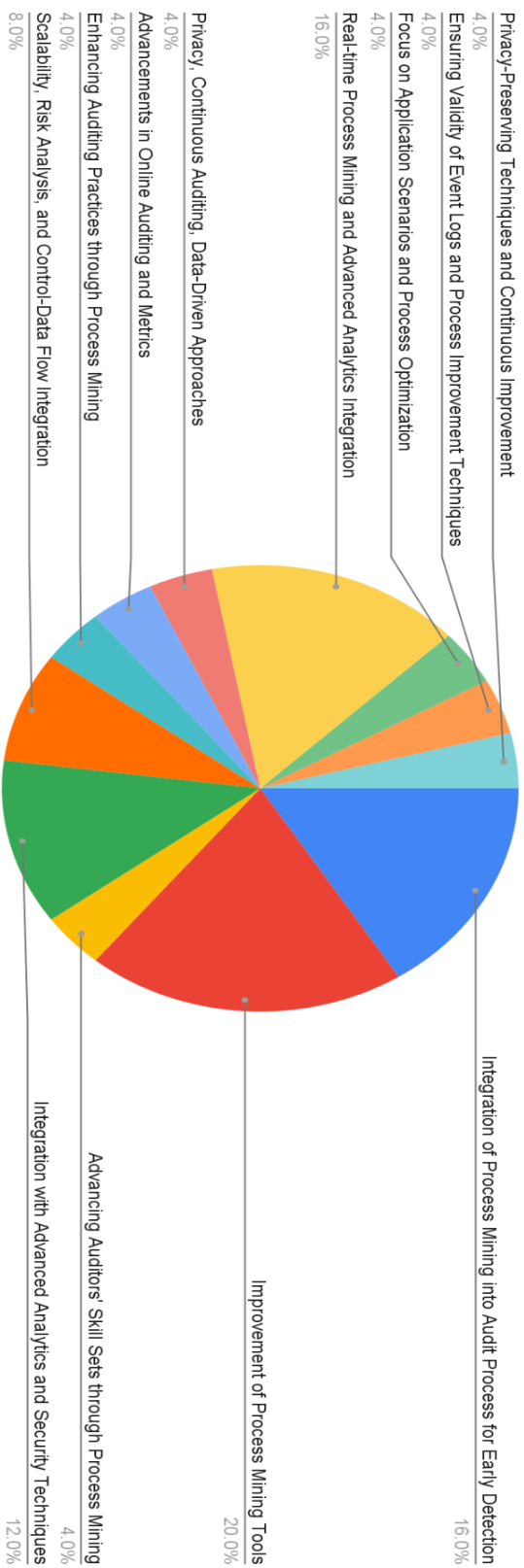


Figure 7. Overview of future direction of process mining in auditing

## **5. Discussion**

The goal of the discussion section is to provide a thorough analysis and explanation of the study's results. The objectives of this study were to examine process mining techniques used in auditing, as well as future directions, benefits, and challenges associated with applying process mining in auditing.

### **5.1. Which types of process mining techniques are frequently reported in auditing research?**

This review of the literature found that various process mining techniques are frequently used in auditing investigations. Diverse techniques, as highlighted by different researchers, furnish auditors with a multifaceted toolkit to tackle auditing intricacies. Jans et al. (2013) underscore the centrality of Process Discovery, while Gehrke (2010) accentuates Conformance Checking's role in comprehending actual processes and ensuring fidelity to predefined models. These techniques empower auditors not only to fathom operational workflows but also to validate their conformity with established benchmarks. Furthermore, Event Log Extraction, as expounded by Jans et al. (2013), emerges as a pivotal foundational step, forming the bedrock for subsequent analysis. The prominence accorded to Resource Analysis, championed by Santoro et al. (2020), Zerbino et al. (2021), and Gehrke (2010), accentuates the appraisal of resource utilisation, encompassing both human and mechanical factors. The cooperative nature of techniques like Social Network Analysis, as illuminated by Jans et al. (2014), and Role Analysis, elucidated by Jans et al. (2011), sheds light on communication patterns and responsibilities' influence on process dynamics. Moreover, Attribute Analysis, presented by Jans et al. (2013), advances an evaluation of data quality tied to process events, enhancing the robustness of insights derived from process mining. De Weerd et al.'s (2013) exposition of Decision Mining and Verification furnishes a vantage point for comprehending decision-making processes and their alignment with regulatory frameworks. Together, these methods enable auditors to get profound understanding of organisational processes, streamline operations, and make sure that specified standards are being followed. It is not surprising that these strategies are used in auditing research given their shown capacity to reveal hidden patterns, identify irregularities, and increase process effectiveness. It's noteworthy that the prominence of Process Discovery and Conformance Checking reflects the need to align operational practices with predefined models, ensuring that processes adhere to established norms. This reaffirms the view held in prior research that maintaining compliance and integrity within processes is paramount for effective auditing. The summary of our findings emphasises both prospective directions for further research as well as the resonance between a variety of process mining techniques and the auditing area. Despite the fact that our study carefully reviewed a portion of the pertinent literature, it's critical to recognise the fact that not all articles in this field were available. Additionally, the relatively modest number of publications within this particular focus may indicate the existence of yet-to-be-examined complexities and changing dynamics in the interplay between technology and auditing practices.



## **5.2. Which benefits and added value in auditing results can be attributed to process mining use?**

We identified through our literature review a plethora of benefits and added value to auditing results due to the implementation of process mining. Auditor insights into complex business processes are improved by the use of process mining tools, increasing process transparency and allowing for a more thorough understanding of process flows and deviations (Dos Santos Garcia et al., 2019; Werner & Gehrke, 2015). With the use of these insights, risk assessment capacities may be improved, social links within processes can be found, and useful data can be extracted from event logs. Additionally, the realisation of the effects of process mining on effectiveness and efficiency, as shown by Accorsi & Stocker (2012), Jans et al. (2010), Zerbino et al. (2018), Dzihni et al. S. (2019), and Siek & Mukti (2021), denotes a change in auditing procedures. Redefining audit procedures through automation assistance, the development of exact process models, greater effectiveness, and efficiency paves the way for audits that are more organised and precise. In addition to its current contributions, the findings also suggest numerous pathways for future research and utilisation of process mining in auditing. Process mining's ability to support continuous auditing (Jans et al., 2013) opens up a path for dynamic and real-time audit monitoring, improving risk management and hastening anomaly discovery. Additionally, as described by Jans et al. (2010), the combination of process mining with advanced analytics opens up a variety of possibilities for more advanced analysis and insights, particularly in intricate financial processes. Process mining has the capacity to cross departmental boundaries (Jans et al., 2013), demonstrating its versatility in creating an all-encompassing approach to auditing that takes into account many facets of an organisation's operations. However, it is crucial to recognise the constraints posed by the use of process mining. When data quality is degraded, the reliance on accurate and thorough event log data may present problems. Process mining must also be implemented successfully, which requires specialised knowledge, potentially making it unavailable to organisations without the necessary tools or experience. The incorporation of process mining techniques into auditing procedures appears, in the end, as a catalyst for profound change. The results of this study support the advantages of process mining in terms of process transparency, risk assessment, efficiency, and other factors, and they also show how it may be used to redefine auditing approaches. The research directions that have been opened up emphasise the dynamic character of process mining's contributions and the possibility of ongoing development.

## **5.3. Which difficulties and obstacles have been found in implementing process mining in auditing?**

A number of difficulties and barriers were discovered during the application of process mining in auditing, according to the literature review. The synthesis of findings surrounding the challenges inherent in integrating process mining techniques into the domain of auditing unearths a multifaceted landscape that demands careful consideration. The study by Tiwari et al. (2008)

emphasises the prevalence of duplicate tasks, necessitating the incorporation of diverse perspectives in process mining to unravel intricate process intricacies. The investigation undertaken by Dos Santos Garcia et al. (2019) and De Weerd et al. (2013) draws attention to the complexity embedded within business processes, compounded by unstructured behaviours that warrant the integration of data-flow insights from logs. This dimension underscores the importance of holistic understanding to capture the essence of these processes, advocating for innovative approaches in process mining. The discerning observation made by Dos Santos Garcia et al. (2019) and Accorsi et al. (2013) highlights the pervasive concern of privacy and security in process mining, amplifying the criticality of ensuring data protection while embracing the potentials offered by this methodology. Further, the study by Werner & Gehrke (2015) and Imran et al. (2023) accentuates the foundational role of data quality and availability, necessitating rigorous measures to mitigate inaccuracies that may undermine the efficacy of process mining in auditing. The hurdles posed by the lack of generalisation and the impact of outliers, as delineated by De Weerd et al. (2013), Zerbino et al. (2018), Jokonowo et al. (2018), Jans & Eulerich (2022), and Santoro et al. (2020), underscore the necessity of robust data handling techniques to ensure the credibility of process mining outcomes. Nonetheless, these insights prompt us to envision the future trajectory of process mining in auditing, holding the promise of transforming auditing practices with enhanced efficiency, transparency, and insight. However, this journey is not without its limitations. The constraints of human judgement and the challenges in achieving widespread adoption, as illuminated by Imran et al. (2023), impel the exploration of automation tools to harness the full potential of process mining. This comprehensive view underscores the necessity for continued research endeavours that delve into refining the methodologies, expanding the tools, and addressing these challenges to unlock the full potential of process mining in enriching auditing practices. Finally, the problems discussed highlight the complexities of incorporating process mining into auditing. These barriers present difficulties, but they also present chances for development and innovation. By overcoming these obstacles, auditing practices may be redefined, allowing for more effective, precise, and insightful techniques to improve organisational procedures and decision-making.

#### **5.4. Which future directions are provided in the literature for process mining's implementation in auditing?**

The literature review identified several intriguing future directions for the implementation of process mining in auditing. Undoubtedly, the exploration of future directions for process mining in auditing, as illuminated by diverse studies like (Dos Santos Garcia et al., 2019), (Werner & Gehrke, 2015), (Jans et al., 2010), and (Santoro et al., 2020), paves a path towards transformative potential while acknowledging critical areas of development and limitation. These forward-looking investigations underscore the dynamic evolution of the field and emphasise strategic avenues for researchers and practitioners alike. The integration of process mining into the audit process, as outlined in (Tiwari et al., 2008), (Dos Santos Garcia et al., 2019), and (Jans et al., 2010), bears significant implications for the acceleration of early detection of anomalies and fraud, leading to informed decision-making and improved audit quality. Concurrently, the emphasis on enhancing

process mining tools, as advocated by (Zerbino et al., 2018), ushers in an era of heightened tool efficiency and effectiveness. This bears relevance not only to auditors but also to the broader landscape of process-oriented domains, as the improvements may cascade across sectors. Nonetheless, this path is not devoid of challenges. The intricacies of process complexity and unstructured behaviours, illuminated by (Dos Santos Garcia et al., 2019) and (Zerbino et al., 2018), imply the necessity for innovative methodologies to capture and model these elusive aspects. Similarly, the integration of advanced analytics and security techniques, as discussed in (Accorsi & Stocker, 2012) and (Accorsi et al., 2013), demands careful orchestration to maintain data integrity and ensure robustness in security implementations. Data quality and availability, underscored by (Werner & Gehrke, 2015) and (Jans et al., 2011), cast a lingering shadow over the efficacy of process mining, necessitating consistent vigilance in data management and curation. In embracing these findings, the field must remain agile and adaptive. Future research, in alignment with the perspectives presented, should actively pursue multidisciplinary collaborations. The confluence of process mining and advanced analytics, as envisioned by (Zerbino et al., 2018), has the potential to usher in a new era of enriched insights. Moreover, the prospect of real-time process mining and integration with advanced analytics, as articulated by (Jans et al., 2011), holds the promise of addressing dynamic operational scenarios in near-real-time. In conclusion, while the roadmap for process mining in auditing is promising, it is incumbent upon researchers and practitioners to collectively navigate the landscape with cautious optimism. By acknowledging the challenges outlined by various authors and harnessing the opportunities delineated in the studies, the discipline can progressively enhance audit practices, enrich decision-making, and catalyse the refinement of audit methodologies in the ever-evolving landscape of technology and business processes.

## **6. Conclusion**

This study embarked on an extensive exploration of the symbiotic relationship between process mining and auditing, unveiling an array of techniques, advantages, challenges, and future directions through meticulous analysis. Guided by four pivotal research questions, our study navigated the complex landscape of this synergy. Commencing with an investigation into prevalent process mining techniques within auditing, we unveiled technologies including process discovery, conformance checking, performance analysis, and social network analysis. Our analysis unveiled the techniques that underpin these processes, demonstrating their utility in uncovering inefficiencies, deviations, and bottlenecks. Concurrently, we delved into the value addition that process mining imparts on auditing practices, encompassing heightened process transparency, effective risk assessment, and invaluable insights obtained from event logs. However, these advancements encountered challenges that underscored the complex nature of implementing process mining in the audit domain. Our findings highlighted difficulties such as the need for refined algorithms, automated aggregation, and visualisation methods to effectively process the intricate data involved. Yet, the scope of our findings transcends the present moment, casting a visionary spotlight on uncharted domains of future directions. Our analysis reveals exciting opportunities as practices and technology develop. The integration of process mining into the audit process emerges as a potent tool for early detection. Efforts directed at refining process mining tools and elevating auditors' skill sets stand as harbingers for further exploration. The call for integration with advanced analytics, scalability enhancements, and the augmentation of online auditing and metrics beckons towards a transformative reshaping of the auditing landscape through the lens of process mining. This horizon also underscores the imperative of addressing privacy concerns, fostering the concept of continuous auditing, and championing data-driven approaches. The culmination of our findings propels the evolution of auditing towards a realm where process mining transcends being a mere tool to emerge as a catalytic and transformative force. The significance of this acquired knowledge resonates in the refinement of practices, the evolution of methodologies, and the pursuit of elevated audit quality. Ultimately, This study resounds as an imperative invitation for a synergistic alliance between these domains, leveraging their combined potentials to sculpt a visionary and intrepid trajectory forward.

### **6.1. Limitations and Further Research**

This study acknowledges the inherent limits that constrain its breadth while also providing a clear path for those exploring the uncharted waters of process mining in auditing. Although the examination of alternative strategies, advantages, difficulties, and directions for the future offers insightful information, the limited availability of current research in this specialised field imposes a limitation. It is still critical to conduct further in-depth research to enlarge and deepen these fields. In addition to shedding light on previously unconsidered concepts, this study emphasises the necessity of scholarly engagement to fill in the gaps and build a solid foundation for the development of the process mining and auditing paradigms.

## Appendix 1. PM-T Code

References	Authors	Year of publication	Number Of Citations	Key words	PM-T
Tiwari, A., Turner, C. J., & Majeed, B. (2008). A review of business process mining: state-of-the-art and future trends. <i>Business Process Management Journal</i> , 14(1), 5-22.	(Tiwari et al., 2008)	2008	274	Process management, Workflow, Computer applications	- Process discovery
dos Santos Garcia, C., Meincheim, A., Junior, E. R. F., Dallagassa, M. R., Sato, D. M. V., Carvalho, D. R., ... & Scalabrin, E. E. (2019). Process mining techniques and applications—A systematic mapping study. <i>Expert Systems with Applications</i> , 133, 260-295.	(Dos Santos Garcia et al., 2019)	2019	245	Process mining Workflow mining Process mining applications Process mining case studies	- Process discovery
De Weerd, J., Schupp, A., Vanderloock, A., & Baesens, B. (2013). Process Mining for the multi-faceted analysis of business processes—A case study in a financial services organisation. <i>Computers in Industry</i> , 64(1), 57-67.	(De Weerd et al., 2013)	2013	181	Process Mining Event log analysis Real-life application Financial services industry	- Process Discovery - Data Preparation and Exploration - Feedback Loop with Business Experts
Accorsi, R., & Stocker, T. (2012, March). On the exploitation of process mining for security audits: the conformance checking	(Accorsi & Stocker, 2012)	2012	130	Business Process Security Audit, Process Mining,	- Conformance Checking

case. In Proceedings of the 27th annual ACM symposium on applied computing (pp. 1709-1716).				Conformance checking, Information Flow Analysis	
Accorsi, R., Stocker, T., & Müller, G. (2013, March). On the exploitation of process mining for security audits: the process discovery case. In Proceedings of the 28th Annual ACM Symposium on Applied Computing (pp. 1462-1468).	(Accorsi et al., 2013)	2013	79	Business process, Security audit, Process mining, Process discovery	- Process Discovery
Werner, M., & Gehrke, N. (2015). Multilevel process mining for financial audits. IEEE Transactions on Services Computing, 8(6), 820-832.	(Werner & Gehrke, 2015)	2015	64	Business Intelligence (BI), financial audits, business process intelligence, process mining, data mining, data analysis, business process modelling, ERP systems, design science research	- Process Discovery
Jans, M. J., Alles, M., & Vasarhelyi, M. A. (2010). Process mining of event logs in auditing: Opportunities and challenges. Available at SSRN 1578912.	(Jans et al., 2010)	2010	57	Event logs, process mining, auditing, continuous auditing	- Process Discovery - Conformance Checking - Performance Analysis - Decision Mining and Verification - Social Network

					Analysis
Jans, M., Alles, M., & Vasarhelyi, M. (2011, April). Process mining of event logs in internal auditing: a case study. In The 2nd International Symposium on Accounting Information Systems, Italy.	(Jans et al., 2011)	2011	55	Process mining, internal auditing, ICFR	<ul style="list-style-type: none"> <li>- Process Discovery</li> <li>- Verification by Attribute Analysis</li> <li>- Social Network Analysis</li> <li>- Role Analysis</li> </ul>
Zerbino, P., Aloini, D., Dulmin, R., & Mininno, V. (2018). Process-mining-enabled audit of information systems: Methodology and an application. Expert Systems with Applications, 110, 80-92.	(Zerbino et al., 2018)	2018	53	Information system audit, error detection, process mining, Business Process Management, Risk Management, Port Community System	<ul style="list-style-type: none"> <li>- Process Discovery</li> <li>- Control-flow Model Construction</li> <li>- Model Enrichment</li> </ul>
Jokonowo, B., Claes, J., Sarno, R., & Rochimah, S. (2018). Process mining in supply chains: a systematic literature review. International Journal of Electrical and Computer Engineering, 8(6), 4626-4636.	(Jokonowo et al., 2018)	2018	22	Supply chain process model Process mining Cross-organizational process Systematic literature review	<ul style="list-style-type: none"> <li>- Process Discovery</li> <li>- Event log Extraction</li> </ul>
Bukhsh, F. A., & Weigand, H. (2012). REA & process mining: How to combine them for auditing. In 6th International Workshop on Value Modeling and Business Ontology, Vienna Austria.	(Bukhsh & Weigand, 2012)	2012	7	Auditing, Customs Control, Service-Oriented Architecture, REA, Process Mining	<ul style="list-style-type: none"> <li>- Event Log Extraction</li> </ul>

Jans, M., & Eulerich, M. (2022). Process mining for financial auditing. In Process Mining Handbook (pp. 445-467). Cham: Springer International Publishing.	(Jans & Eulerich, 2022)	2022	7	Financial auditing · Internal auditing · External auditing · Process mining	- Process Discovery - Conformance Checking - Root Cause Analysis - Process Enhancement
Santoro, F. M., Revoredo, K. C., Costa, R. M., & Barboza, T. M. (2020). Process Mining Techniques in Internal Auditing: A Stepwise Case Study. iSys-Brazilian Journal of Information Systems, 13(4), 48-76.	(Santoro et al., 2020)	2020	1	Process mining, Process Auditing, Conformance Checking	- Process Discovery - Social Network Analysis - Conformance Checking - Performance Analysis - Resource Analysis
Imran, M., Hamid, S., & Ismail, M. A. (2023). Advancing Process Audits with Process Mining: A systematic review of trends, challenges, and opportunities. IEEE Access.	(Imran et al., 2023)	2023	0	Audits, business process audits, process compliance checking, process mining, systematic literature review	- Process Discovery - Process Enhancement
Abdelwahed, A. S., Abu-Musa, A. A., Moubarak, H., & Badawy, H. A. THE ADOPTION OF BIG DATA ANALYTICS IN THE EXTERNAL AUDITING: Bibliometric and Content Analyses.	(Abdelwahed et al., 2023)	2023	0	Big Data, Big Data Analytics, Data Analytics, Audit Data Analytics, External Auditing, Audit Process, Audit Quality, Bibliometric Analysis, Content Analysis	- Process Discovery - Conformance Checking - Performance Analysis - Root Cause Analysis



## Appendix 2. AV-A Code

References	Authors	Year of publication	Number Of Citations	Key words	AV-A
Tiwari, A., Turner, C. J., & Majeed, B. (2008). A review of business process mining: state-of-the-art and future trends. <i>Business Process Management Journal</i> , 14(1), 5-22.	(Tiwari et al., 2008)	2008	274	Process management, Workflow, Computer applications	
dos Santos Garcia, C., Meincheim, A., Junior, E. R. F., Dallagassa, M. R., Sato, D. M. V., Carvalho, D. R., ... & Scalabrin, E. E. (2019). Process mining techniques and applications—A systematic mapping study. <i>Expert Systems with Applications</i> , 133, 260-295.	(Dos Santos Garcia et al., 2019)	2019	245	Process mining Workflow mining Process mining applications Process mining case studies	- Efficiency and Effectiveness - Process Compliance - Evidence-based Auditing
De Weerd, J., Schupp, A., Vanderloock, A., & Baesens, B. (2013). Process Mining for the multi-faceted analysis of business processes—A case study in a financial services organisation. <i>Computers in Industry</i> , 64(1), 57-67.	(De Weerd et al., 2013)	2013	181	Process Mining Event log analysis Real-life application Financial services industry	- Process Improvement and Awareness - Analysing Structured and Less Structured Information Systems - Increased Efficiency - Real-Life Application and Value Demonstration

Accorsi, R., & Stocker, T. (2012, March). On the exploitation of process mining for security audits: the conformance checking case. In Proceedings of the 27th annual ACM symposium on applied computing (pp. 1709-1716).	(Accorsi & Stocker, 2012)	2012	130	Business Process Security Audit, Process Mining, Conformance checking, Information Flow Analysis	<ul style="list-style-type: none"> <li>- Providing Powerful Tools for Compliance Checking</li> <li>- Improve Security Audit</li> </ul>
Accorsi, R., Stocker, T., & Müller, G. (2013, March). On the exploitation of process mining for security audits: the process discovery case. In Proceedings of the 28th Annual ACM Symposium on Applied Computing (pp. 1462-1468).	(Accorsi et al., 2013)	2013	79	Business process, Security audit, Process mining, Process discovery	<ul style="list-style-type: none"> <li>- Offering Efficient Analysis of Security Aspects in Business Processes</li> <li>- Automating Security Audits</li> </ul>
Werner, M., & Gehrke, N. (2015). Multilevel process mining for financial audits. IEEE Transactions on Services Computing, 8(6), 820-832.	(Werner & Gehrke, 2015)	2015	64	Business Intelligence (BI), financial audits, business process intelligence, process mining, data mining, data analysis, business process modelling, ERP systems, design science research	<ul style="list-style-type: none"> <li>- Enhanced Efficiency</li> <li>- Automation Support</li> <li>- Precise Process Models</li> </ul>
Jans, M. J., Alles, M., & Vasarhelyi, M. A. (2010). Process mining of event logs in auditing: Opportunities and challenges. Available at SSRN 1578912.	(Jans et al., 2010)	2010	57	Event logs, process mining, auditing, continuous auditing	<ul style="list-style-type: none"> <li>- Revolutionise auditing practices by improving effectiveness and uncovering valuable insights.</li> <li>- Detect Anomalies</li> <li>- Auditors Can Gain</li> </ul>

					<ul style="list-style-type: none"> <li>iInsights into Business Processes</li> <li>- Uncover Frauds</li> <li>- Comprehensive and Independent Record of System Activities</li> </ul>
<p>Jans, M., Alles, M., &amp; Vasarhelyi, M. (2011, April). Process mining of event logs in internal auditing: a case study. In The 2nd International Symposium on Accounting Information Systems, Italy.</p>	(Jans et al., 2011)	2011	55	<p>Process mining, internal auditing, ICFR</p>	<ul style="list-style-type: none"> <li>- Richness of the Event Log</li> <li>- Analysis of the Entire Population</li> <li>- Process Visualisation</li> <li>- Contribute to its Effectiveness in Uncovering Internal Control Weaknesses and Anomalies.</li> </ul>
<p>Zerbino, P., Aloini, D., Dulmin, R., &amp; Mininno, V. (2018). Process-mining-enabled audit of information systems: Methodology and an application. Expert Systems with Applications, 110, 80-92.</p>	(Zerbino et al., 2018)	2018	53	<p>Information system audit, error detection, process mining, Business Process Management, Risk Management, Port Community System</p>	<ul style="list-style-type: none"> <li>- In-depth Analysis</li> <li>- Easier Automation</li> <li>- Reduced Invasiveness</li> <li>- Improve Flexibility</li> </ul>
<p>Jokonowo, B., Claes, J., Sarno, R., &amp; Rochimah, S. (2018). Process mining in supply chains: a systematic literature review. International Journal of Electrical and Computer Engineering, 8(6), 4626-4636.</p>	(Jokonowo et al., 2018)	2018	22	<p>Supply chain process model Process mining Cross-organizational process Systematic literature review</p>	<ul style="list-style-type: none"> <li>- Increased Transparency</li> </ul>

Bukhsh, F. A., & Weigand, H. (2012). REA & process mining: How to combine them for auditing. In 6th International Workshop on Value Modeling and Business Ontology, Vienna Austria.	(Bukhsh & Weigand, 2012)	2012	7	Auditing, Customs Control, Service-Oriented Architecture, REA, Process Mining	- Improved Process Transparency
Jans, M., & Eulerich, M. (2022). Process mining for financial auditing. In Process Mining Handbook (pp. 445-467). Cham: Springer International Publishing.	(Jans & Eulerich, 2022)	2022	7	Financial auditing · Internal auditing · External auditing · Process mining	- Integration with Advanced Analytics
Santoro, F. M., Revoredo, K. C., Costa, R. M., & Barboza, T. M. (2020). Process Mining Techniques in Internal Auditing: A Stepwise Case Study. iSys-Brazilian Journal of Information Systems, 13(4), 48-76.	(Santoro et al., 2020)	2020	1	Process mining, Process Auditing, Conformance Checking	- Process Transparency and Visualization
Imran, M., Hamid, S., & Ismail, M. A. (2023). Advancing Process Audits with Process Mining: A systematic review of trends, challenges, and opportunities. IEEE Access.	(Imran et al., 2023)	2023	0	Audits, business process audits, process compliance checking, process mining, systematic literature review.	- Full population based audit

<p>Abdelwahed, A. S.,  Abu-Musa, A. A.,  Moubarak, H., &amp; Badawy,  H. A. THE ADOPTION OF  BIG DATA ANALYTICS IN  THE EXTERNAL  AUDITING: Bibliometric  and Content Analyses.</p>	<p>(Abdelwahed  et al., 2023)</p>	<p>2023</p>	<p>0</p>	<p>Big Data, Big  Data Analytics,  Data Analytics,  Audit Data  Analytics,  External  Auditing, Audit  Process, Audit  Quality,  Bibliometric  Analysis,  Content  Analysis.</p>	
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### Appendix 3. AD Code

References	Authors	year of publication	Number Of Citations	Key words	A-D
Tiwari, A., Turner, C. J., & Majeed, B. (2008). A review of business process mining: state-of-the-art and future trends. <i>Business Process Management Journal</i> , 14(1), 5-22.	(Tiwari et al., 2008)	2008	274	Process management, Workflow, Computer applications	- Duplicate Tasks - Mining Perspectives
dos Santos Garcia, C., Meincheim, A., Junior, E. R. F., Dallagassa, M. R., Sato, D. M. V., Carvalho, D. R., ... & Scalabrin, E. E. (2019). Process mining techniques and applications—A systematic mapping study. <i>Expert Systems with Applications</i> , 133, 260-295.	(Dos Santos Garcia et al., 2019)	2019	245	Process mining Workflow mining Process mining applications Process mining case studies	- Process Complexity - Privacy and Security Concerns - Data Quality and Availability
De Weerd, J., Schupp, A., Vanderloock, A., & Baesens, B. (2013). Process Mining for the multi-faceted analysis of business processes—A case study in a financial services organisation. <i>Computers in Industry</i> , 64(1), 57-67.	(De Weerd et al., 2013)	2013	181	Process Mining Event log analysis Real-life application Financial services industry	- Complex Process Environments - Unstructured Process Behaviour

Accorsi, R., & Stocker, T. (2012, March). On the exploitation of process mining for security audits: the conformance checking case. In Proceedings of the 27th annual ACM symposium on applied computing (pp. 1709-1716).	(Accorsi & Stocker, 2012)	2012	130	Business Process Security Audit, Process Mining, Conformance checking, Information Flow Analysis	- The Consideration of Data-flow Information from Logs
Accorsi, R., Stocker, T., & Müller, G. (2013, March). On the exploitation of process mining for security audits: the process discovery case. In Proceedings of the 28th Annual ACM Symposium on Applied Computing (pp. 1462-1468).	(Accorsi et al., 2013)	2013	79	Business process, Security audit, Process mining, Process discovery	- The Need for Algorithms Capable of Extracting Both Control and Data Flow - Privacy Concerns - The Presentation of Audit Results is Also an Area for Improvement, Aiming for More User-friendly and Intelligible Output.
Werner, M., & Gehrke, N. (2015). Multilevel process mining for financial audits. IEEE Transactions on Services Computing, 8(6), 820-832.	(Werner & Gehrke, 2015)	2015	64	Business Intelligence (BI), financial audits, business process intelligence, process mining, data mining, data analysis, business process modelling, ERP systems, design science research	- Lack of Generalization - Deadlock in Process Models

<p>Jans, M. J., Alles, M., &amp; Vasarhelyi, M. A. (2010). Process mining of event logs in auditing: Opportunities and challenges. Available at SSRN 1578912.</p>	<p>(Jans et al., 2010)</p>	<p>2010</p>	<p>57</p>	<p>Event logs, process mining, auditing, continuous auditing</p>	<p>- Transcending the limitations of relying solely on input data.</p>
<p>Jans, M., Alles, M., &amp; Vasarhelyi, M. (2011, April). Process mining of event logs in internal auditing: a case study. In The 2nd International Symposium on Accounting Information Systems, Italy.</p>	<p>(Jans et al., 2011)</p>	<p>2011</p>	<p>55</p>	<p>Process mining, internal auditing, ICFR</p>	<p>- Lack of Generalizability</p>
<p>Zerbino, P., Aloini, D., Dulmin, R., &amp; Mininno, V. (2018). Process-mining-enabled audit of information systems: Methodology and an application. Expert Systems with Applications, 110, 80-92.</p>	<p>(Zerbino et al., 2018)</p>	<p>2018</p>	<p>53</p>	<p>Information system audit, error detection, process mining, Business Process Management, Risk Management, Port Community System</p>	<p>- The exclusion of potential outliers from the log should be conducted with a high level of awareness.  - The Capability to Conduct on-line IS Audits Through PM is Not Mature Yet.  - Narrow Scope  - Lack of Automatic Tools  - The Complexity Index Equalizes All the Process Variants Without Evaluating their Severity.  - A Certain, Reasonably-low Amount of Manual Work is Still Needed</p>



					Because of the Specificities that the Context of Analysis Could Present
Jokonowo, B., Claes, J., Sarno, R., & Rochimah, S. (2018). Process mining in supply chains: a systematic literature review. <i>International Journal of Electrical and Computer Engineering</i> , 8(6), 4626-4636.	(Jokonowo et al., 2018)	2018	22	Supply chain process model Process mining Cross-organizational process Systematic literature review	<ul style="list-style-type: none"> <li>- Process Complexity</li> <li>- Tool Limitations</li> <li>- Privacy and Confidentiality</li> </ul>
Bukhsh, F. A., & Weigand, H. (2012). REA & process mining: How to combine them for auditing. In 6th International Workshop on Value Modeling and Business Ontology, Vienna Austria.	(Bukhsh & Weigand, 2012)	2012	7	Auditing, Customs Control, Service-Oriented Architecture, REA, Process Mining	<ul style="list-style-type: none"> <li>- Complexity of Inter-organizational Processes</li> <li>- Privacy and Security Concerns</li> </ul>
Jans, M., & Eulerich, M. (2022). Process mining for financial auditing. In <i>Process Mining Handbook</i> (pp. 445-467). Cham: Springer International Publishing.	(Jans & Eulerich, 2022)	2022	7	Financial auditing · Internal auditing · External auditing · Process mining	<ul style="list-style-type: none"> <li>- Privacy and Data Security</li> <li>- Handling Complex Processes</li> <li>- Interpretation Challenges</li> </ul>

<p>Santoro, F. M., Revoredo, K. C., Costa, R. M., &amp; Barboza, T. M. (2020). Process Mining Techniques in Internal Auditing: A Stepwise Case Study. <i>iSys-Brazilian Journal of Information Systems</i>, 13(4), 48-76.</p>	<p>(Santoro et al., 2020)</p>	<p>2020</p>	<p>1</p>	<p>Process mining, Process Auditing, Conformance Checking</p>	<ul style="list-style-type: none"> <li>- Data Quality and Completeness</li> <li>- Privacy and Data Security</li> <li>- Interpretation Challenges</li> <li>- Process Maturity</li> </ul>
<p>Imran, M., Hamid, S., &amp; Ismail, M. A. (2023). Advancing Process Audits with Process Mining: A systematic review of trends, challenges, and opportunities. <i>IEEE Access</i>.</p>	<p>(Imran et al., 2023)</p>	<p>2023</p>	<p>0</p>	<p>Audits, business process audits, process compliance checking, process mining, systematic literature review.</p>	<ul style="list-style-type: none"> <li>- Log extraction and transformation issue</li> <li>- Privacy Concerns</li> <li>- Integration of PM into existing audit landscape</li> <li>- Data availability and accuracy challenge</li> <li>- Representational and algorithmic bias</li> <li>- Handling noise and anomalies</li> <li>- Complexity challenge</li> </ul>
<p>Abdelwahed, A. S., Abu-Musa, A. A., Moubarak, H., &amp; Badawy, H. A. THE ADOPTION OF BIG DATA ANALYTICS IN THE EXTERNAL AUDITING: Bibliometric and Content Analyses.</p>	<p>(Abdelwahed et al., 2023)</p>	<p>2023</p>	<p>0</p>	<p>Big Data, Big Data Analytics, Data Analytics, Audit Data Analytics, External Auditing, Audit Process, Audit Quality, Bibliometric Analysis, Content Analysis.</p>	<ul style="list-style-type: none"> <li>- Process Complexity</li> <li>- Human Judgment and Interpretation</li> <li>- Limited Adoption</li> </ul>

#### Appendix 4. FD Code

References	Authors	Year of publication	Source Title	Number Of Citations	Key words	FD
Tiwari, A., Turner, C. J., & Majeed, B. (2008). A review of business process mining: state-of-the-art and future trends. Business Process Management Journal, 14(1), 5-22.	(Tiwari et al., 2008)	2008	Business Process Management Journal	274	Process management, Workflow, Computer applications	
dos Santos Garcia, C., Meincheim, A., Junior, E. R. F., Dallagassa, M. R., Sato, D. M. V., Carvalho, D. R., ... & Scalabrin, E. E. (2019). Process mining techniques and applications–A systematic mapping study. Expert Systems with Applications, 133, 260-295.	(Dos Santos Garcia et al., 2019)	2019	Expert Systems with Applications	245	Process mining Workflow mining Process mining applications Process mining case studies	- Integration with Big Data Technologies - Real-time Process Mining

<p>De Weerd, J., Schupp, A., Vanderloock, A., &amp; Baesens, B. (2013). Process Mining for the multi-faceted analysis of business processes—A case study in a financial services organisation. <i>Computers in Industry</i>, 64(1), 57-67.</p>	<p>(De Weerd et al., 2013)</p>	<p>2013</p>	<p>Computers in Industry</p>	<p>181</p>	<p>Process Mining Event log analysis Real-life application Financial services industry</p>	<p>- Integration with Advanced Analytics</p>
<p>Accorsi, R., &amp; Stocker, T. (2012, March). On the exploitation of process mining for security audits: the conformance checking case. In <i>Proceedings of the 27th annual ACM symposium on applied computing</i> (pp. 1709-1716).</p>	<p>(Accorsi &amp; Stocker, 2012)</p>	<p>2012</p>	<p>Information Systems and Applications</p>	<p>130</p>	<p>Business Process Security Audit, Process Mining, Conformance checking, Information Flow Analysis</p>	<p>- Integrating PM with information flow techniques to enhance security audits and business process analysis - Developing specialised techniques - Addressing scalability challenges</p>

<p>Accorsi, R., Stocker, T., &amp; Müller, G. (2013, March). On the exploitation of process mining for security audits: the process discovery case. In Proceedings of the 28th Annual ACM Symposium on Applied Computing (pp. 1462-1468).</p>	<p>(Accorsi et al., 2013)</p>	<p>2013</p>	<p>Information Systems and Applications</p>	<p>79</p>	<p>Business process, Security audit, Process mining, Process discovery</p>	<ul style="list-style-type: none"> <li>- Utilising process mining for risk analysis</li> <li>- Integrating control and data flow extraction</li> </ul>
<p>Werner, M., &amp; Gehrke, N. (2015). Multilevel process mining for financial audits. IEEE Transactions on Services Computing, 8(6), 820-832.</p>	<p>(Werner &amp; Gehrke, 2015)</p>	<p>2015</p>	<p>IEEE Transactions on Services Computing</p>	<p>64</p>	<p>Business Intelligence (BI), financial audits, business process intelligence, process mining, data mining, data analysis, business process modelling, ERP systems, design science research</p>	<ul style="list-style-type: none"> <li>- Generalisation</li> <li>- Deadlock Handling</li> <li>- Extension to other ERP systems</li> <li>- Integration of Control Flow and Data Flow</li> </ul>

<p>Jans, M. J., Alles, M., &amp; Vasarhelyi, M. A. (2010). Process mining of event logs in auditing: Opportunities and challenges. Available at SSRN 1578912.</p>	<p>(Jans et al., 2010)</p>	<p>2010</p>	<p>SSRN</p>	<p>57</p>	<p>Event logs, process mining, auditing, continuous auditing</p>	<ul style="list-style-type: none"> <li>- Develop tools and methodologies</li> <li>- Integrating process mining techniques and leveraging event log insights can enhance auditing practices and contribute to the ongoing evolution of the field</li> </ul>
<p>Jans, M., Alles, M., &amp; Vasarhelyi, M. (2011, April). Process mining of event logs in internal auditing: a case study. In The 2nd International Symposium on Accounting Information Systems, Italy.</p>	<p>(Jans et al., 2011)</p>	<p>2011</p>	<p>In The 2nd International Symposium on Accounting Information Systems, Italy.</p>	<p>55</p>	<p>Process mining, internal auditing, ICFR</p>	<ul style="list-style-type: none"> <li>- Explore the application of process mining</li> </ul>

<p>Zerbino, P., Aloini, D., Dulmin, R., &amp; Mininno, V. (2018). Process-mining-enabled audit of information systems: Methodology and an application. Expert Systems with Applications, 110, 80-92.</p>	<p>(Zerbino et al., 2018)</p>	<p>2018</p>	<p>Expert System with Application</p>	<p>53</p>	<p>Information system audit, error detection, process mining, Business Process Management, Risk Management, Port Community System</p>	<ul style="list-style-type: none"> <li>- Leading to advancements in online auditing</li> <li>- Improved metrics for process analysis</li> <li>- Enhanced contextualization of non-conformances in IS audits</li> </ul>
<p>Jokonowo, B., Claes, J., Sarno, R., &amp; Rochimah, S. (2018). Process mining in supply chains: a systematic literature review. International Journal of Electrical and Computer Engineering, 8(6), 4626-4636.</p>	<p>(Jokonowo et al., 2018)</p>	<p>2018</p>	<p>International Journal of Electrical and Computer Engineering</p>	<p>22</p>	<p>Supply chain process model Process mining Cross-organizational process Systematic literature review</p>	<ul style="list-style-type: none"> <li>- Continuous Auditing</li> <li>- Data-Driven Audit Approach</li> </ul>

Bukhsh, F. A., & Weigand, H. (2012). REA & process mining: How to combine them for auditing. In 6th International Workshop on Value Modeling and Business Ontology, Vienna Austria.	(Bukhsh & Weigand, 2012)	2012	6th International Workshop on Value Modeling and Business Ontology, Vienna Austria	7	Auditing, Customs Control, Service-Oriented Architecture, REA, Process Mining	
Jans, M., & Eulerich, M. (2022). Process mining for financial auditing. In Process Mining Handbook (pp. 445-467). Cham: Springer International Publishing.	(Jans & Eulerich, 2022)	2022	Cham: Springer International Publishing	7	Financial auditing, Internal auditing, External auditing, Process mining	- Integration with Advanced Analytics
Santoro, F. M., Revoredo, K. C., Costa, R. M., & Barboza, T. M. (2020). Process Mining Techniques in Internal Auditing: A Stepwise Case Study. iSys-Brazilian Journal of Information Systems, 13(4), 48-76.	(Santoro et al., 2020)	2020	Brazilian Journal of Information Systems	1	Process mining, Process Auditing, Conformance Checking	- Integration with Data Science



<p>Imran, M., Hamid, S., &amp; Ismail, M. A. (2023). Advancing Process Audits with Process Mining: A systematic review of trends, challenges, and opportunities. IEEE Access.</p>	<p>(Imran et al., 2023)</p>	<p>2023</p>	<p>Engineering &amp; Management Sciences, Quetta 87300, Pakistan</p>	<p>0</p>	<p>Audits, business process audits, process compliance checking, process mining, systematic literature review.</p>	<p>- Development of methods to ensure the validity and reliability of event logs used for process mining based audits.</p>
<p>Abdelwahed, A. S., Abu-Musa, A. A., Moubarak, H., &amp; Badawy, H. A. THE ADOPTION OF BIG DATA ANALYTICS IN THE EXTERNAL AUDITING: Bibliometric and Content Analyses.</p>	<p>(Abdelwahed et al., 2023)</p>	<p>2023</p>	<p>International Journal of Auditing and Accounting Studies</p>	<p>0</p>	<p>Big Data, Big Data Analytics, Data Analytics, Audit Data Analytics, External Auditing, Audit Process, Audit Quality, Bibliometric Analysis, Content Analysis.</p>	<p>- Real-time Process Mining</p>

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- Abdelwahed, A. S., Abu-Musa, A. A., Moubarak, H., & Badawy, H. A. THE ADOPTION OF BIG DATA ANALYTICS IN THE EXTERNAL AUDITING: Bibliometric and Content Analyses.
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