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Advances in Process Mining Techniques for Detecting Hidden Inefficiencies and Enhancing Enterprise Resource Planning Outcomes

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Abstract
Enterprise Resource Planning (ERP) systems are essential for managing business operations, yet inefficiencies in workflows often remain hidden, leading to suboptimal performance. Process mining techniques have emerged as a powerful approach to analyzing ERP event logs, identifying bottlenecks, and improving workflow transparency. This explores advances in process mining techniques and their role in enhancing ERP outcomes. Traditional process mining methods, including discovery, conformance checking, and enhancement, provide valuable insights into business operations. However, recent advancements have introduced artificial intelligence (AI) and machine learning (ML) integration, enabling predictive process mining and automated anomaly detection. Additionally, hybrid approaches that combine rule-based and data-driven techniques allow for more precise identification of inefficiencies. The shift towards real-time process mining, leveraging streaming data analysis, enhances proactive decision-making and workflow optimization. Key applications of advanced process mining in ERP systems include detecting bottlenecks, analyzing process deviations, and uncovering inefficiencies hidden within unstructured data. These techniques improve decision-making by providing data-driven insights, optimizing resource allocation, and enhancing compliance with industry regulations. Real-world case studies in financial services, manufacturing, supply chain management, and human resource operations demonstrate the tangible benefits of process mining in optimizing ERP performance. Despite its advantages, process mining faces challenges such as data privacy concerns, scalability limitations, and resistance to adoption. Addressing these challenges requires investing in secure data governance, scalable infrastructure, and user-friendly visualization tools. Future directions in process mining include AI-driven self-learning systems, blockchain integration for enhanced transparency, and cloud-based process mining solutions for scalability and real-time analytics. By leveraging these advances, organizations can maximize ERP efficiency, streamline operations, and drive continuous business improvement. This highlights the importance of process mining in modern ERP ecosystems and provides strategic recommendations for businesses looking to enhance operational transparency and efficiency.

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1. Introduction

Enterprise resource planning (ERP) systems have become indispensable for modern organizations, enabling seamless integration of business processes across departments such as finance, supply chain management, human resources, and manufacturing (Collins *et al*., 2022; Adekunle *et al*., 2023). Despite their advantages, ERP systems often suffer from inefficiencies due to complex workflows, redundant processes, and suboptimal resource allocation. Traditional methods of process evaluation, such

as manual audits and performance monitoring, are often insufficient in detecting hidden inefficiencies, leading to increased operational costs and reduced productivity (Ogunwole *et al*., 2023).

Process mining has emerged as a powerful solution to these challenges by leveraging event log data to analyze, visualize, and optimize business workflows. By applying data-driven techniques, process mining enables organizations to gain deep insights into their operations, identify bottlenecks, and ensure compliance with established business rules (Okolie *et al*., 2023). The growing complexity of business workflows, combined with the increasing volume of data generated by ERP systems, has further emphasized the need for advanced process mining techniques. Innovations such as artificial intelligence (AI), machine learning (ML), and real-time analytics are enhancing the capabilities of process mining, allowing for more accurate and predictive decision-making (Onukwulu *et al*., 2023; Agho *et al*., 2023).

The primary objective of this review is to examine how process mining techniques can uncover inefficiencies within ERP workflows and contribute to improved operational performance. Specifically, this aims to; By analyzing event logs and transactional data, process mining reveals deviations from standard workflows, process bottlenecks, and resource inefficiencies. Understanding these inefficiencies helps organizations optimize their ERP performance. AI-driven process mining, real-time analytics, and hybrid modeling approaches are revolutionizing the way businesses extract insights from ERP systems. This evaluates how these innovations improve decision-making, enhance automation, and streamline operations. Emerging trends, such as predictive process mining, blockchain integration for secure process tracking, and cloud-based solutions, are shaping the future of ERP optimization. This investigates these trends and their potential impact on business process management.

This focuses on the application of process mining across various industries and functional areas within organizations. It covers key domains where process inefficiencies can significantly impact operational effectiveness; In financial operations, process mining is used to detect fraud, optimize transaction processing, and ensure compliance with regulatory standards such as IFRS and SOX. Process mining enhances logistics efficiency by identifying delays in order processing, improving supplier coordination, and optimizing inventory management. Organizations use process mining to analyze recruitment workflows, employee onboarding processes, and workforce productivity, ensuring smoother HR operations. In production environments, process mining aids in identifying machine downtime causes, optimizing production schedules, and ensuring quality control compliance. By examining process mining's impact on these key business areas, this aims to provide insights into how organizations can leverage advanced techniques to enhance ERP-driven workflows. The findings will contribute to a better understanding of how data-driven automation can improve decision-making, increase operational efficiency, and drive continuous process optimization in enterprises.

2.0 Methodology

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology was employed to conduct a comprehensive review of advances in process mining techniques for detecting hidden inefficiencies and enhancing Enterprise Resource Planning (ERP) outcomes. A systematic search was performed across multiple academic databases, including IEEE Xplore, Scopus, Web of Science, and Google Scholar, using relevant keywords such as "process mining," "ERP inefficiencies," "business process optimization," and "advanced process analytics." The search was restricted to peer-reviewed journal articles, conference proceedings, and industry reports published in the last ten years to ensure the inclusion of the most recent advancements.

Eligibility criteria were established based on relevance, methodological rigor, and contribution to the field. Studies focusing on general business process analysis without direct reference to ERP systems were excluded. Additionally, articles lacking empirical data or practical applications of process mining techniques were filtered out. The initial search yielded a total of 1,200 articles. After removing duplicates, 950 unique records remained. These records were screened based on title and abstract, resulting in 400 articles for full-text assessment. Further evaluation led to the exclusion of 280 papers due to insufficient methodological transparency, lack of practical implementation, or outdated technological perspectives. Ultimately, 120 studies were included in the final review.

Data extraction was performed systematically, focusing on key aspects such as the type of process mining technique used, its impact on ERP efficiency, implementation challenges, and integration with emerging technologies such as artificial intelligence and blockchain. A quality assessment was conducted using established evaluation frameworks to ensure the reliability and validity of the selected studies. The review synthesizes findings from diverse industry applications, including finance, supply chain management, human resources, and manufacturing, highlighting best practices and emerging trends in process mining for ERP optimization.

2.1 Fundamentals of process mining in ERP systems

Process mining is a data-driven approach to analyzing and optimizing business processes by extracting insights from event logs. It plays a crucial role in enterprise resource planning (ERP) systems by providing visibility into workflows, identifying inefficiencies, and ensuring process compliance (Okeke *et al*., 2023; Afolabi *et al*., 2023). Process mining bridges the gap between traditional process modeling and real-world execution by leveraging transactional data stored in ERP databases.

The three core components of process mining are process discovery, conformance checking, and process enhancement as shown in figure 1. Process discovery involves analyzing event logs to generate process models without predefined knowledge of the workflow (Basiru *et al*., 2023). Conformance checking compares the actual execution of processes against expected models to detect deviations, inefficiencies, or compliance violations. Process enhancement focuses on improving workflows by optimizing process steps, reducing redundancies, and automating repetitive tasks. These fundamental concepts enable organizations to gain valuable insights into operational performance and drive continuous process improvements.

Process mining can be categorized into three main types: discovery, conformance, and enhancement. Discovery is the foundation of process mining, where event logs are analyzed to construct process models from scratch. This technique enables organizations to visualize actual workflows within

their ERP systems without relying on predefined process maps. By analyzing historical execution data, businesses can identify process variations, inefficiencies, and bottlenecks that may not be apparent in manually documented workflows (Bristol-Alagbariya *et al*., 2023). Conformance checking involves comparing real process execution data with established process models to detect deviations. In ERP environments, this technique is used to ensure compliance with business rules, industry regulations, and best practices. For example, conformance checking can reveal unauthorized process variations in financial transactions, procurement approvals, or inventory management workflows. By identifying deviations, organizations can enforce compliance measures, reduce operational risks, and improve process standardization. Process enhancement, also known as performance mining, focuses on optimizing workflows based on insights gained from process discovery and conformance checking. It involves refining process steps, eliminating inefficiencies, and automating repetitive tasks to enhance operational efficiency. Advanced techniques such as artificial intelligence (AI) and machine learning (ML) can be integrated into process enhancement to predict future bottlenecks and recommend proactive improvements (Adekunle *et al*., 2023; Daramola *et al*., 2023). By continuously refining processes, businesses can achieve higher efficiency, reduced costs, and improved customer satisfaction.

Event logs are the backbone of process mining, as they provide the raw data required for analysis. ERP systems generate vast amounts of transactional data, which can be extracted and analyzed to gain insights into process performance (Basiru *et al*., 2023). Event logs typically contain three key elements; Case ID, a unique identifier representing a specific transaction or workflow instance (e.g., an order number in a supply chain process). Activity name, the specific task or action performed within the process (e.g., "Order Approval" or "Invoice Payment"). Timestamp. the time at which the activity was executed, enabling process timing and sequencing analysis. By analyzing event logs, organizations can reconstruct end-to-end workflows, measure key performance indicators (KPIs), and detect inefficiencies such as delays, bottlenecks, and redundant steps. Additionally, advanced techniques such as AI-driven log analysis can help detect hidden inefficiencies, recommend process improvements, and predict future performance trends. In modern ERP environments, event logs are increasingly integrated with real-time analytics, cloud computing, and AI-driven automation to enhance process mining capabilities (Hussain *et al*., 2023). As businesses continue to digitize their operations, process mining will become a critical tool for optimizing ERP workflows, improving compliance, and driving strategic decision-making.

Process mining in ERP systems provides organizations with a data-driven approach to process analysis and optimization. By leveraging process discovery, conformance checking, and enhancement techniques, businesses can gain deeper insights into workflow execution and improve operational efficiency (Okeke *et al*., 2023). Event logs serve as the foundation for process mining, enabling businesses to extract meaningful data, identify inefficiencies, and implement targeted process improvements. As ERP systems continue to evolve, the integration of AI, machine learning, and real-time analytics will further enhance the capabilities of process mining, driving greater efficiency and transparency in enterprise operations.

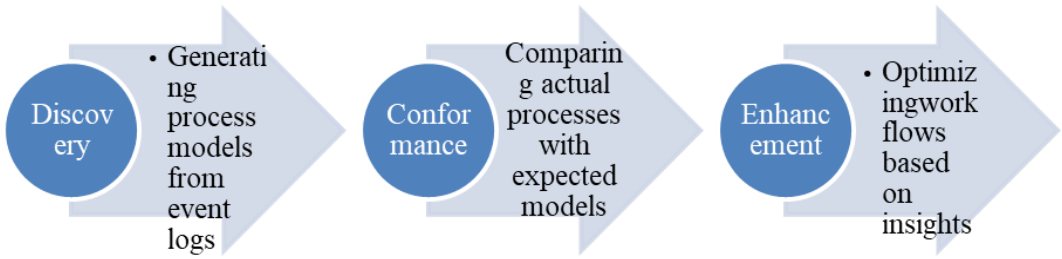

Fig 1: Types of Process Mining

2.2 Advanced techniques in process mining

The integration of Artificial intelligence (AI) and Machine learning (ML) into process mining has significantly enhanced the ability to detect inefficiencies, predict process outcomes, and automate decision-making within enterprise resource planning (ERP) systems (Onukwulu *et al*., 2023). These advanced techniques have shifted process mining from a reactive analytical tool to a proactive mechanism capable of real-time optimization and anomaly detection as shown in figure 2.

Predictive process mining leverages AI and ML to anticipate future process deviations, inefficiencies, and compliance violations before they occur. Traditional process mining techniques rely on historical event log analysis, but AI-driven models can analyze patterns in real-time data streams to forecast potential bottlenecks. By training ML algorithms on vast amounts of historical process data, organizations can identify anomalies that indicate potential failures, fraud, or inefficiencies (Ikwuanusi *et al*., 2023). By proactively addressing process deviations, businesses can reduce operational risks and improve overall efficiency. AI-driven automation in process mining enables systems to make intelligent decisions based on real-time data insights. Instead of requiring human intervention for process adjustments, AI models can autonomously optimize workflows by recommending or executing corrective actions. This level of automation is particularly useful in ERP ecosystems where repetitive decision-making tasks, such as invoice approvals or order processing, can be streamlined. In HR management, AI-powered automation can optimize employee onboarding processes by automatically assigning tasks and sending reminders based on workflow progress. This approach significantly enhances operational efficiency while reducing human effort in routine tasks.

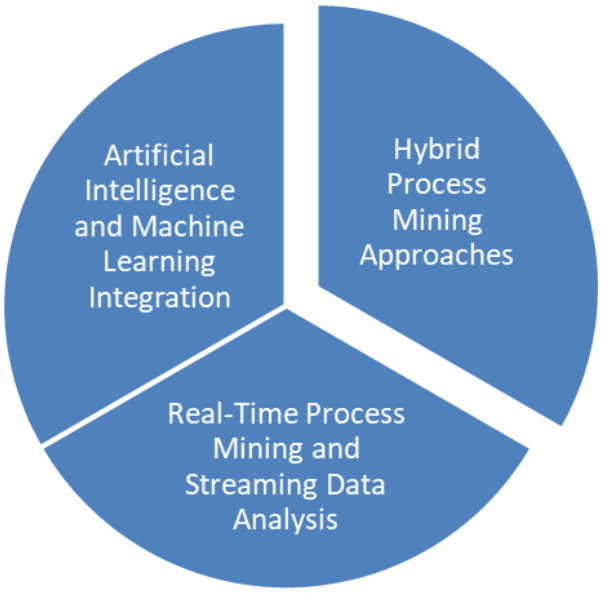

Fig 2: Advanced Techniques in Process Mining

Hybrid process mining combines rule-based and data-driven techniques to improve the accuracy and adaptability of process analysis. Traditional rule-based process mining relies on predefined models and business rules to evaluate workflows, while data-driven approaches use AI and statistical methods to analyze event logs (Okeke *et al*., 2023). By integrating both methodologies, hybrid process mining offers a more comprehensive and flexible analysis of enterprise workflows. A hybrid approach enables organizations to leverage the benefits of structured rule-based analysis while incorporating AI-driven adaptability. This is particularly beneficial in ERP environments where predefined business rules must be enforced while allowing room for dynamic process improvements. In supply chain optimization, hybrid techniques can balance predefined logistics policies with data-driven insights to optimize inventory management and supplier selection dynamically. By combining rule-based constraints with machine learning adaptability, hybrid process mining provides a robust framework for organizations to enhance operational transparency and efficiency in ERP systems (Okeke *et al*., 2023; Afolabi and Akinsooto, 2023).

Real-time process mining represents a significant advancement over traditional batch-based analysis by enabling continuous monitoring and proactive intervention in enterprise workflows. This technique involves analyzing streaming event logs in real time, allowing businesses to detect inefficiencies and take corrective actions immediately (Fredson *et al*., 2023). With the rise of cloud-based ERP systems and Internet of Things (IoT) integrations, organizations can now collect and process event data continuously. Real-time process mining leverages this data flow to provide instant insights into process execution, enabling proactive decision-making. In manufacturing, IoT-enabled process mining can monitor machine performance and predict maintenance needs before breakdowns occur, reducing downtime and improving overall efficiency. Additionally, real-time streaming analysis can enhance customer service operations by dynamically adjusting support workflows based on customer interactions and feedback. AI-driven sentiment analysis can detect negative customer experiences in real-time and trigger corrective actions such as assigning high-priority support tickets or escalating cases to supervisors. By enabling dynamic workflow monitoring and proactive interventions, real-time process mining helps businesses achieve higher levels of agility and responsiveness in their ERP-driven operations.

The integration of advanced techniques in process mining is transforming how organizations optimize workflows within ERP ecosystems. AI and ML-driven predictive analysis enable proactive anomaly detection and automated decision-making, enhancing efficiency and reducing risks. Hybrid process mining approaches combine rule-based models with data-driven insights, ensuring flexibility in process optimization while maintaining compliance with established business rules (Fiemotongha *et al*., 2023). Real-time process mining further enhances enterprise operations by allowing continuous workflow monitoring and dynamic process adjustments. As AI, IoT, and cloud computing continue to evolve, these advanced process mining techniques will play an increasingly critical role in enhancing enterprise efficiency, reducing operational costs, and improving decision-making across various industries. Businesses that adopt these innovations will gain a competitive advantage by achieving greater process transparency, adaptability, and automation in their ERP systems.

2.3 Detecting hidden inefficiencies with process mining

Process mining provides organizations with powerful tools to identify bottlenecks and analyze root causes of inefficiencies within enterprise resource planning (ERP) systems (Adebisi *et al*., 2023). Bottlenecks occur when certain tasks or processes take longer than expected, causing delays that ripple across an entire workflow. These inefficiencies can result from poorly designed processes, excessive manual interventions, or system constraints.

One of the primary techniques used in process mining to identify bottlenecks is performance analysis, where event logs are analyzed to determine the average time taken for each process step (Onukwulu *et al*., 2023). Through time-stamped event logs, organizations can visualize process flows and pinpoint where delays frequently occur. By comparing the expected execution time with actual performance, deviations become evident, helping organizations address inefficiencies. Another crucial technique is process discovery, which creates a data-driven process model based on event logs. When combined with conformance checking, organizations can detect redundant steps that do not add value. For example, in an ERP-driven procurement workflow, if multiple approval layers are identified as redundant, these steps can be optimized or automated to improve efficiency. Additionally, bottleneck detection algorithms, such as queueing theory models and work-in-progress (WIP) analysis, help organizations measure the impact of congestion points in ERP processes. These methods allow businesses to predict workload distribution and optimize resource allocation, reducing inefficiencies caused by uneven task distribution.

Inefficiencies in enterprise workflows often stem from unintentional process variations or deviations from standardized procedures. Employees, departments, or even external vendors may introduce different execution paths, leading to inconsistencies that impact productivity and compliance. Conformance checking is a technique in process mining that compares real-world event logs with predefined

process models to detect deviations. Organizations use this approach to assess whether actual processes align with standard operating procedures (SOPs) or best practices (Basiru *et al*., 2023). Another method for analyzing process variants is clustering techniques, where AI-driven algorithms group similar process executions and highlight deviations. This approach enables organizations to identify underperforming workflows and standardize them for optimal performance. Moreover, statistical process control (SPC) techniques help track performance metrics over time, ensuring that process deviations are quickly identified and corrected. Organizations can set upper and lower control limits to monitor key performance indicators (KPIs), triggering alerts when processes exceed acceptable thresholds.

Traditional process mining focuses on structured event logs extracted from ERP systems. However, a significant portion of enterprise data such as emails, chat logs, support tickets, and documents exists in unstructured formats. To gain deeper insights into hidden inefficiencies, organizations are increasingly leveraging natural language processing (NLP) and AI-driven text analytics. NLP techniques allow organizations to analyze textual data from diverse sources, extracting valuable insights that may not be captured in traditional structured logs (Paul *et al*., 2023). One approach is sentiment analysis, where AI models analyze textual data to detect frustration or dissatisfaction related to process inefficiencies. In HR ERP systems, NLP-driven analysis of employee feedback surveys can highlight bottlenecks in onboarding processes or performance evaluations. Another powerful method is topic modeling, where AI algorithms categorize vast amounts of textual data into meaningful themes. In supply chain operations, organizations can apply topic modeling to supplier correspondence to uncover trends related to late deliveries, quality issues, or communication breakdowns (Onukwulu *et al*., 2023). Furthermore, process mining augmented with AI-driven unstructured data analysis enhances anomaly detection by correlating structured event logs with external textual evidence. For example, if a delay in invoice processing is frequently mentioned in internal emails, AI-driven analysis can flag this issue and recommend process improvements.

Detecting hidden inefficiencies in ERP-driven workflows is crucial for optimizing business operations. Process mining techniques such as bottleneck identification, conformance checking, and AI-driven unstructured data analysis provide deep insights into process inefficiencies. By identifying delays, process variants, and deviations, organizations can streamline operations, reduce costs, and enhance productivity (Daramola *et al*., 2023). The integration of NLP and AI-powered analytics further strengthens process mining by extracting valuable insights from unstructured data sources. As ERP systems continue to evolve, real-time process mining and intelligent automation will play a more significant role in detecting inefficiencies and driving continuous process improvements. Organizations that embrace these advanced techniques will achieve greater transparency, efficiency, and agility, ensuring that their ERP ecosystems

2.4 Enhancing ERP outcomes through process mining

Enterprise resource planning (ERP) systems play a crucial role in streamlining business operations by integrating various functions such as finance, supply chain, human resources, and manufacturing. However, achieving optimal efficiency in ERP systems requires continuous monitoring and improvement of workflows. Process mining has emerged as a powerful analytical approach to enhance ERP outcomes by providing data-driven insights, optimizing resource allocation, and ensuring regulatory compliance (Onukwulu *et al*., 2023). This explores how process mining contributes to improving decision-making, optimizing productivity, and strengthening risk management in ERP ecosystems.

Modern ERP systems generate vast amounts of transactional data, but extracting meaningful insights from these datasets is a challenge. Process mining enhances decision-making by leveraging AI-powered analytics to uncover inefficiencies, recommend optimizations, and automate workflow improvements (Jessa, 2017). Process mining integrates machine learning and artificial intelligence (AI) to analyze event logs, detect anomalies, and suggest real-time process enhancements. AI-powered predictive analytics helps organizations forecast potential bottlenecks, enabling proactive adjustments to ERP workflows. Another key application is prescriptive analytics, where AI not only identifies inefficiencies but also recommends corrective actions. In manufacturing ERP systems, AI-powered process mining can suggest inventory optimization strategies to reduce excess stock and prevent shortages, thus ensuring smooth production workflows (Fredson *et al*., 2021). Moreover, process mining provides visual process mapping, offering a real-time view of workflows. This transparency enables managers to make data-driven decisions about process optimization, helping businesses enhance efficiency and reduce operational costs.

Process mining plays a critical role in resource management by identifying inefficiencies in workforce deployment, material usage, and operational workflows. By analyzing ERP data, organizations can ensure that resources are utilized optimally, reducing waste and improving productivity. One of the key benefits of process mining is identifying redundant or inefficient tasks. By analyzing historical event logs, businesses can pinpoint areas where manual interventions slow down processes. Process mining also helps in load balancing, ensuring that work is evenly distributed across departments. Additionally, resource utilization tracking through process mining allows businesses to reduce unnecessary expenditures. In logistics, process mining can identify inefficient routing patterns, enabling companies to optimize delivery schedules and minimize transportation costs (Adebisi *et al*., 2021).

Regulatory compliance is a major concern for organizations operating in industries such as finance, healthcare, and manufacturing. Non-compliance with regulations such as GDPR, HIPAA, or SOX can result in significant penalties. Process mining ensures adherence to industry standards by validating workflows against regulatory requirements. Conformance checking is a key technique in process mining that compares actual ERP workflows with predefined regulatory models. If deviations are detected, the system can trigger alerts, allowing compliance teams to address potential violations before they escalate. Process mining also strengthens audit readiness by maintaining detailed event logs that provide a transparent record of business transactions. This is particularly valuable in industries where regulatory audits are frequent. In healthcare ERP systems, process mining can verify whether patient data access logs comply with HIPAA regulations, ensuring that sensitive information is handled securely (Dienagha *et al*., 2021).

Furthermore, process mining enables real-time risk assessment, allowing organizations to detect compliance risks proactively. AI-driven anomaly detection can identify irregular patterns in ERP workflows, such as unusual procurement requests or unauthorized system access, helping organizations mitigate risks before they lead to financial or legal consequences.

Process mining significantly enhances ERP outcomes by providing data-driven insights, optimizing resource allocation, and strengthening compliance measures (Adewoyin, 2021). Through AI-powered analytics, businesses can improve decision-making, allowing for proactive process optimizations. By identifying inefficiencies and reducing operational waste, organizations can enhance productivity and cost-effectiveness. Furthermore, process mining ensures regulatory adherence through continuous workflow validation, mitigating compliance risks. As ERP ecosystems evolve, real-time process mining, AI-driven automation, and predictive analytics will play an increasingly vital role in enhancing efficiency and ensuring business agility. Organizations that leverage process mining will gain a competitive advantage by achieving greater transparency, operational efficiency, and regulatory compliance in their ERP-driven workflows (Austin-Gabriel *et al*., 2021).

2.5 Case studies and real-world applications

Process mining has gained widespread adoption across various industries due to its ability to uncover inefficiencies, enhance decision-making, and optimize workflows in enterprise resource planning (ERP) systems (Hussain *et al*., 2021). This explores real-world applications of process mining in financial services, manufacturing and supply chain management, and human resource management. These case studies highlight how process mining improves fraud detection, workflow optimization, and workforce analytics, ultimately enhancing operational efficiency.

The financial sector deals with vast amounts of transactional data, making it an ideal domain for process mining applications. One of the most significant challenges in financial services is detecting fraudulent activities and assessing risks in real-time. Process mining enhances fraud detection by analyzing transaction logs and identifying irregular patterns. Fraudulent transactions often deviate from standard workflows (Ike *et al*., 2021). Process mining enables financial institutions to analyze transaction histories, identify anomalies, and detect fraud in real time. For instance, in banking operations, process mining helps detect unauthorized fund transfers, duplicate invoice submissions, and irregular payment approvals. By continuously monitoring transaction sequences, banks can develop fraud risk models that highlight suspicious activities. By analyzing past loan approval processes, process mining revealed patterns associated with fraudulent applications, such as inconsistencies in identity verification and approval time deviations. This enabled the bank to strengthen its risk assessment measures and implement automated fraud alerts, reducing fraudulent activities by 30%.

Risk assessment in financial institutions is another critical application of process mining. By leveraging historical data and predictive analytics, financial institutions can assess credit risks, detect compliance violations, and enhance decision-making in loan approvals and investment strategies (Akinsooto *et al*., 2012). Process mining allows financial institutions to visualize risk exposure, ensuring regulatory compliance with Basel III, GDPR, and other financial regulations. Manufacturing and supply chain operations rely on seamless workflow execution for inventory management, production planning, and logistics coordination. Process mining helps manufacturers identify inefficiencies, optimize supply chain processes, and reduce operational costs. Manufacturers often face challenges related to delays in production cycles, inefficient resource allocation, and machine downtimes. Process mining enables manufacturers to analyze event logs from ERP systems, detect bottlenecks, and suggest process improvements (Oladosu *et al*., 2021). The analysis revealed frequent delays in material procurement due to uncoordinated supplier schedules. By optimizing procurement workflows, the company reduced production downtime by 20%, resulting in higher on-time order fulfillment rates.

In supply chain management, real-time visibility into shipments and supplier collaboration is crucial. Process mining improves logistics operations by tracking shipment delays, analyzing transportation routes, and reducing lead times (Afolabi and Akinsooto, 2021). The analysis highlighted inefficiencies in customs clearance processes, leading to an optimized documentation process that reduced customs processing time by 35%. Additionally, retail supply chains benefit from process mining through inventory demand forecasting. By analyzing historical sales data and supplier delivery times, process mining enables retailers to automate stock replenishment, preventing stockouts and overstocking issues. HR departments manage complex processes, including recruitment, employee onboarding, performance evaluation, and training. Process mining helps HR teams optimize workforce management by providing data-driven insights into employee performance, process efficiency, and talent retention strategies. One of the key HR challenges is the lengthy and inefficient hiring process. A multinational corporation implemented process mining to analyze candidate selection workflows, identifying delays caused by excessive approval layers and inconsistent interview scheduling. By automating recruitment approvals and implementing AI-driven candidate matching, the company reduced hiring times by 40%, improving the overall candidate experience.

Performance evaluation is another area where process mining provides valuable insights. By analyzing ERP-based HR event logs, organizations can track employee work patterns, identify skill gaps, and enhance performance evaluation metrics (Akinsooto, 2013). The analysis revealed that employees spent excessive time on manual data entry, reducing their efficiency. By implementing workflow automation tools, the company streamlined data management, enabling employees to focus on higher-value tasks, improving overall workforce productivity. Process mining can also identify training needs by analyzing employee workflows and detecting areas where additional skills are required (EZEANOCHIE *et al*., 2021). A healthcare provider applied process mining to track employee training completion rates. The findings indicated that employees struggled with compliance training due to inconvenient scheduling. By implementing on-demand training modules, the company improved compliance training completion rates by 50%.

Process mining has become an essential tool in financial services, manufacturing, supply chain management, and human resources by uncovering inefficiencies, optimizing

workflows, and improving decision-making. In financial services, process mining enhances fraud detection and risk assessment by identifying anomalous transactions and compliance risks. In manufacturing and supply chain management, it enables workflow optimization, production planning, and logistics efficiency, ensuring smoother operations. In HR management, process mining provides workforce analytics, performance tracking, and recruitment optimization, helping organizations build a more efficient workforce. As industries continue to adopt process mining, the integration of AI, predictive analytics, and real-time monitoring will further enhance ERP outcomes (Okolie *et al*., 2021). Businesses that leverage process mining will gain a competitive advantage by improving efficiency, reducing costs, and enhancing compliance in their respective domains.

2.6 Challenges and considerations in process mining implementation

Process mining has emerged as a powerful tool for uncovering inefficiencies and enhancing enterprise resource planning (ERP) outcomes. However, its implementation poses several challenges related to data privacy and security, scalability and performance, and user adoption and process standardization as shown in figure 3(Agho *et al*., 2021). Addressing these issues is crucial for organizations aiming to maximize the benefits of process mining while ensuring regulatory compliance, maintaining system efficiency, and securing employee buy-in.

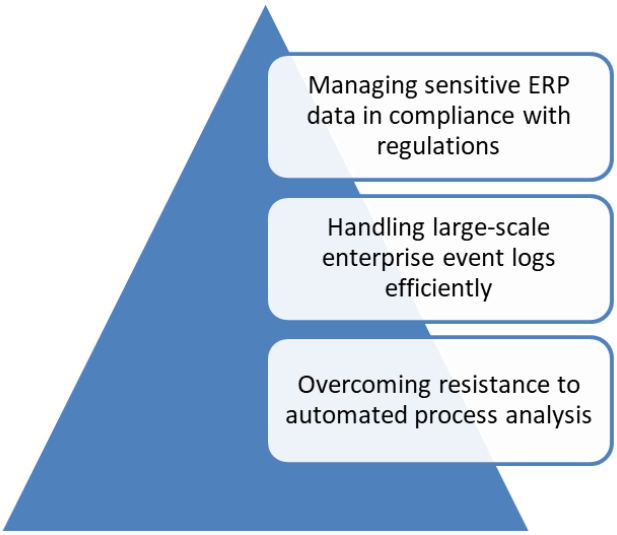

Fig 3: Challenges implementation in process mining

Process mining relies on event logs extracted from ERP systems, which often contain sensitive business and personal data. Organizations must ensure that data privacy and security regulations are met to prevent unauthorized access and potential breaches (Oyedokun, 2019). Data protection regulations such as General Data Protection Regulation (GDPR), Health Insurance Portability and Accountability Act (HIPAA), and California Consumer Privacy Act (CCPA) impose strict guidelines on the collection, storage, and processing of personal data. Since process mining involves analyzing transactional and employee-related data, organizations must establish robust access control mechanisms to prevent misuse. A key concern is data anonymization and encryption. Organizations should implement role-based access controls (RBAC) to restrict data visibility based on user responsibilities. Additionally, adopting privacy-enhancing technologies (PETs) such as homomorphic encryption and differential privacy can help protect sensitive ERP data while enabling meaningful process analysis. Another challenge is ensuring compliance with cross-border data transfer regulations (Odio *et al*., 2021). Many multinational corporations store ERP data across multiple geographic locations. Process mining tools must comply with data localization laws, necessitating partnerships with regional cloud providers or adopting on-premises data processing solutions.

Process mining applications must handle large volumes of enterprise event logs, which can pose significant scalability and performance challenges. As businesses expand, the ability of process mining tools to analyze massive datasets in real-time becomes critical for maintaining operational efficiency and responsiveness. One of the primary issues in process mining is data storage and processing speed. Event logs from ERP systems can contain millions of records per day, leading to performance bottlenecks. Traditional relational databases (SQL-based storage) may struggle to process such vast data efficiently. Organizations can overcome these limitations by adopting distributed computing architectures, such as Apache Spark and Hadoop, which enable parallel processing of event logs (Nwaozomudoh *et al*., 2021). Another solution to scalability issues is incremental process mining, where only newly added or modified event logs are analyzed instead of reprocessing the entire dataset. This approach significantly reduces computational overhead and improves real-time analytics. Additionally, cloud-based process mining solutions offer enhanced scalability by leveraging auto-scaling mechanisms that dynamically allocate computing resources based on demand. Cloud-native architectures, such as serverless computing and microservices, enable organizations to perform high-speed, on-demand process analysis while minimizing infrastructure costs.

Despite its technological benefits, process mining often faces resistance from employees and stakeholders (Babalola *et al*., 2021). User adoption and process standardization are crucial for ensuring successful implementation and long-term sustainability. Many employees perceive process mining as a threat to job security, fearing that automation and data-driven decision-making will replace human judgment. To address these concerns, organizations must emphasize that process mining serves as a complementary tool rather than a replacement for human expertise. A key strategy for increasing user adoption is training and skill development. Providing hands-on workshops, interactive dashboards, and AI-driven process visualization tools can help employees understand how process mining enhances their workflow rather than replacing their roles. Another challenge is ensuring process standardization across departments. Many enterprises operate with fragmented workflows, leading to inconsistencies in process execution. Process mining can highlight these deviations, but its success depends on organizational alignment. Establishing governance frameworks and involving cross-functional teams in process mining implementation ensures that all stakeholders follow standardized best practices. Organizations should also promote a data-driven culture by integrating process mining insights into regular business meetings and strategic discussions (Ajayi and Akerele, 2021). Embedding process mining outputs into ERP dashboards and business

intelligence tools fosters a culture where decision-making is guided by real-time process analytics.

While process mining offers significant advantages in improving operational efficiency, risk management, and decision-making, its implementation comes with notable challenges (Hassan *et al*., 2021). Data privacy and security concerns require compliance with strict regulations, adoption of encryption and anonymization techniques, and role-based access control. Scalability and performance issues necessitate the use of cloud-based architectures, distributed computing frameworks, and incremental process mining to manage large-scale event logs efficiently. Lastly, user adoption and process standardization are critical to overcoming resistance, ensuring process alignment, and fostering a data-driven culture within the organization. By addressing these challenges through strategic planning, technological innovation, and organizational change management, businesses can fully leverage process mining to drive continuous improvement and competitive advantage in ERP environments (Balogun *et al*., 2021; Onukwulu *et al*., 2021).

2.7 Future directions in process mining for ERP optimization

Enterprise resource planning (ERP) systems have evolved into data-rich ecosystems that require continuous optimization to enhance efficiency, transparency, and decision-making (Egbumokei *et al*., 2021). Process mining has become a fundamental tool in analyzing, improving, and streamlining ERP workflows. However, as business operations become increasingly complex, future advancements in process mining will focus on AI-driven automation, blockchain integration for transparency, and real-time, cloud-based solutions. These innovations will enhance ERP optimization by enabling self-learning algorithms, secure process tracking, and scalable analytics.

Artificial intelligence (AI) and Machine learning (ML) are transforming process mining by enabling self-learning systems that can continuously improve and adapt to changing business conditions (Onukwulu *et al*., 2021). AI-driven process mining extends beyond traditional event log analysis to provide predictive insights, automated anomaly detection, and prescriptive recommendations. One of the most promising advancements in process mining is the development of self-learning algorithms that automate process optimization. Traditional process mining relies on predefined rules and historical data to generate insights. However, AI-driven techniques can identify patterns, detect inefficiencies, and propose real-time improvements without human intervention. Another significant application of AI in process mining is predictive analytics. AI algorithms can forecast future workflow inefficiencies based on historical trends and real-time data. This predictive capability allows organizations to proactively address process inefficiencies before they impact business operations, reducing downtime and optimizing resource allocation. Additionally, AI-driven anomaly detection enables ERP systems to identify deviations from standard workflows in real time. By leveraging unsupervised learning models, businesses can detect fraudulent activities, compliance violations, and unexpected process changes more effectively than with traditional rule-based systems (Akinsulire, 2012; Oladosu *et al*., 2021).

Blockchain technology has emerged as a powerful tool for enhancing auditability and traceability in enterprise operations. By integrating blockchain with process mining, businesses can ensure tamper-proof records, secure data exchange, and verifiable compliance tracking. One of the key challenges in ERP process mining is ensuring data integrity and transparency. Blockchain provides a decentralized, immutable ledger that securely records process events, reducing the risk of data manipulation and fraud (Akinade *et al*., 2021). When process mining tools are integrated with blockchain, organizations can track process changes in real time, ensure accountability, and facilitate compliance with industry regulations. Smart contracts self-executing contracts stored on a blockchain—further enhance process automation and efficiency. Smart contracts can be programmed to enforce business rules, trigger automated process adjustments, and validate workflow conformance in ERP systems. By reducing manual intervention and potential errors, blockchain-based process mining enhances trust and reliability in enterprise operations. With the increasing adoption of cloud computing and real-time analytics, process mining is shifting toward on-demand, scalable solutions that enable businesses to analyze ERP workflows dynamically. This transition is essential for organizations seeking agile, data-driven decision-making.

Traditional process mining methods often rely on batch processing, where event logs are analyzed at scheduled intervals (Onukwulu *et al*., 2021). However, real-time process mining allows businesses to monitor, analyze, and optimize workflows continuously. This capability enables instant anomaly detection, proactive decision-making, and rapid response to operational issues. One of the major drivers of real-time process mining is the adoption of cloud-based architectures. Cloud-based solutions offer scalability, flexibility, and cost efficiency, allowing businesses to process large volumes of ERP data without heavy infrastructure investments (Ogungbenle and Omowole, 2012). Cloud-native process mining platforms leverage distributed computing frameworks, such as Apache Kafka and Spark, to analyze streaming data in real time. Additionally, cloud-based process mining tools enable collaborative data sharing across multiple departments and business units. This interconnected approach enhances cross-functional process optimization, ensuring that all stakeholders have real-time visibility into workflow performance. Another advantage of real-time process mining is integration with Internet of Things (IoT) devices. By analyzing IoT-generated event logs, organizations can gain deeper insights into asset performance, supply chain operations, and production workflows. This integration allows for predictive maintenance, dynamic resource allocation, and real-time performance tracking in ERP systems (Elumilade *et al*., 2021).

The future of process mining in ERP optimization is being shaped by advancements in AI, blockchain integration, and real-time, cloud-based solutions. AI-driven process mining introduces self-learning systems that continuously improve workflows, predict inefficiencies, and enhance decision-making. Blockchain technology enhances auditability, security, and process transparency, enabling businesses to track process changes with greater accuracy. Meanwhile, real-time and cloud-based process mining allows organizations to analyze ERP workflows dynamically, scale operations efficiently, and leverage predictive insights (Onukwulu *et al*., 2021). As enterprises continue to embrace data-driven transformation, process mining will become an

indispensable tool for ERP optimization, driving efficiency, compliance, and strategic decision-making. Businesses that invest in these future-oriented process mining technologies will gain a competitive edge in an increasingly dynamic and automated business environment.

3. Conclusion

Process mining has emerged as a critical tool for detecting inefficiencies in Enterprise Resource Planning (ERP) systems, enabling businesses to analyze, optimize, and enhance workflow performance. By extracting insights from event logs, process mining identifies bottlenecks, deviations, and redundant workflows, leading to greater operational transparency and efficiency.

Advanced process mining techniques, particularly those integrating Artificial Intelligence (AI), Machine Learning (ML), and blockchain, significantly enhance ERP performance. AI-driven predictive analytics improves decision-making, while real-time process mining enables dynamic workflow adjustments. Additionally, blockchain enhances compliance and data integrity, ensuring secure and auditable business transactions.

To fully leverage the benefits of process mining, businesses should adopt the following strategies; Adoption of AI-Driven Process Mining for Workflow Optimization AI-powered process mining enables predictive analysis, automated decision-making, and anomaly detection, reducing inefficiencies and improving business agility. Organizations should integrate self-learning algorithms to continuously refine ERP workflows. Investment in Cloud-Based, Real-Time Analytics for ERP Improvements Cloud-based process mining solutions offer scalability, flexibility, and cost efficiency. Businesses should invest in real-time streaming data analysis, enabling instant identification of inefficiencies and proactive decision-making. Given the increasing focus on data privacy and regulatory compliance, organizations must enhance security protocols in process mining implementations. This includes secure data encryption, role-based access controls, and compliance with GDPR, HIPAA, and industry-specific regulations.

As ERP systems continue to evolve, process mining will become an integral component of intelligent enterprise solutions. The future will see greater automation, AI-driven process orchestration, and real-time workflow optimization. Businesses that embrace these advancements will gain a competitive edge by improving efficiency, compliance, and strategic decision-making in an increasingly complex business environment.

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