THESIS

PROPOSAL OF FORMALIZED SERVICE LEVEL AGREEMENTS (SLAs) USING PROCESS MINING (CASE STUDY IN LOGISTIC COMPANY)

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Supervisor:
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TESIS

USULAN *SERVICE LEVEL AGREEMENT* (SLA) YANG DIFORMALKAN DENGAN *PROCESS MINING* (STUDI KASUS DI PERUSAHAAN LOGISTIK)

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PROGRAM STUDI MAGISTER MANAJEMEN TEKNOLOGI
SEKOLAH INTERDISIPLIN MANAJEMEN DAN TEKNOLOGI
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
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DECLARATION OF ORIGINALITY

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I, at this moment, declare that this thesis is the result of my own investigation, except where otherwise stated. I also state that it had not been submitted as a whole for any degree at any institution. If this statement is proven incorrectly in the future, I am willing to be prosecuted under the applicable law.

Surabaya, 1 Juli 2024
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PROPOSAL OF FORMALIZED SERVICE LEVEL AGREEMENTS (SLAs) USING PROCESS MINING (CASE STUDY IN LOGISTIC COMPANY)

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ABSTRACT

Service Level Agreements (SLAs) define performance expectations between providers and customers. In the logistics industry, where efficiency and timely delivery are critical, SLAs play a crucial role in ensuring customer satisfaction. However, X's Limited Liability Company (LLC) does not yet have the formalized SLAs. Consequently, the lack of formalized SLAs in X's LLC has led to late deliveries and inconsistencies in service delivery. This study addresses this challenge using Process Mining (PM) to formalize SLAs. The event log is run with the PM tool Apromore to reveal the actual processes involved in service delivery. A further time perspective analysis is carried out to formalize SLAs to establish the measurable KPIs such as "*On-Time Delivery Rates*" and "*Order Cycle Time.*" The variant analysis is done by classifying the products category following Global Product Classification (GPC). Then, a formalized SLA by segment is proposed, offering clear, measurable, and attainable service level targets that align with the company's operational capabilities and strategic objectives. Based on PM analysis, mainly on the time perspective analysis, resulted the average case duration of each segment. The food and beverage segment has an average case duration of 1.47 days; the healthcare segment exhibits an average case duration of 1.71 days; the electrical supplies segment shows an average case duration of 1.53 days; and the building products segment has a significantly longer average case duration of 3.83 days. Following this result, X's LLC can measure their "on-time delivery rates" and "order cycle time." By formalizing SLAs based on these insights, the X's LLC can better manage expectations, optimize operations, and improve overall service delivery. This research highlights the potential of PM to enhance SLA management and establish the measurable KPIs in the logistics industry.

Keywords: Service Level Agreements (SLAs), Process Mining, Logistic, Apromore.

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USULAN *SERVICE LEVEL AGREEMENT* (SLA) YANG DIFORMALISASI DENGAN *PROCESS MINING* (STUDI KASUS DI PERUSAHAAN LOGISTIK)

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ABSTRAK

Service Level Agreement (SLA) menyatakan ekspektasi kinerja antara penyedia layanan dan pelanggan. Dalam industri logistik, efisiensi dan ketepatan waktu pengiriman sangat penting, SLA berperan peran penting dalam menentukan kepuasan pelanggan. Namun, PT. X belum memiliki SLA formal. Akibatnya, SLA yang belum terformalisasi di PT. X menyebabkan keterlambatan pengiriman dan inkonsistensi dalam layanan. Penelitian ini mengatasi tantangan ini dengan menggunakan Process Mining (PM) untuk memformalkan SLA. Event log diaplikasikan pada Apromore untuk mengungkapkan proses aktual yang terlibat dalam pelayanan. Analisis perspektif waktu dilakukan untuk memformalkan SLA untuk menetapkan KPI yang terukur seperti "Tingkat Pengiriman Tepat Waktu" dan "Waktu Siklus Pelayanan". Analisis varian dilakukan dengan mengklasifikasikan kategori produk berdasarkan *Global Product Classification* (GPC). Kemudian, diusulkan SLA yang diformalkan berdasarkan segmen, yang menawarkan target tingkat layanan yang jelas, terukur, dan dapat dicapai yang selaras dengan kemampuan operasional dan tujuan strategis perusahaan. Berdasarkan analisis PM, terutama analisis perspektif waktu, diperoleh rata-rata durasi kasus pada setiap segmen. Segmen makanan dan minuman memiliki rata-rata durasi kasus 1.47 hari; segmen layanan kesehatan menunjukkan durasi kasus rata-rata 1.71 hari; segmen pasokan listrik menunjukkan durasi kasus rata-rata 1.53 hari; dan segmen produk bangunan memiliki rata-rata durasi kasus yang jauh lebih lama yaitu 3.83 hari. Berdasarkan hasil ini, PT. X dapat mengukur "tingkat pengiriman tepat waktu" dan "waktu siklus pelayanan". Dengan memformalkan SLA, PT. X dapat mengelola ekspektasi, mengoptimalkan operasional, dan meningkatkan layanan secara keseluruhan dengan lebih baik. Penelitian ini menekankan pada potensi PM untuk meningkatkan manajemen SLA dan menetapkan KPI yang terukur dalam industri logistik.

Kata kunci: *Service Level Agreement* (SLA), *Process Mining*, Logistik, Apromore

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I would love to declare my loftiest appreciation to Allah SWT, who always gives me strength and patience so that I can finish my thesis entitled "Proposal of Formalized Service Level Agreements (SLAs) using Process Mining (Case Study in Logistic Company)" well. The completion of this thesis can not be separated from the help and support of other parties. Therefore, on this occasion, I would also like to thank:

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I realize there are still many shortcomings in this thesis. I expect any advice and suggestions for improving the next research. Hopefully, it will benefit others.

Surabaya, July 2024

The Author

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CHAPTER 1
INTRODUCTION

1.1 Background of The Study

SLAs are the backbone of the logistics sector's accountability and performance metrics. They define the level of service expected by a customer, laying out the metrics by which service is measured, as well as the remedies or penalties should agreed-upon service levels are not achieved (MAGER, 2013). In the logistics industry, the precision and specificity of SLAs are crucial, as they directly influence customer satisfaction, resource allocation, and the overall efficiency of operations. However, traditional SLAs often lack formalization, leading to inconsistent service experiences and disputes between logistics providers and their customers (Trienekens et al., 2004).

X’s Limited Liability Company (LLC), one of Indonesia’s state-owned enterprises in the logistics sector, has made significant strides in embracing digital transformation by implementing an enterprise system in 2019. This system has been designed to integrate various aspects of their operations, from service’s procure-to-pay, work order fulfillment, and facilitating real-time data access. However, the increasing adoption of digital solutions has brought both opportunities and challenges, especially in relation to their current objectives (right goods, right quantity, and on time)—the absence of formalized SLAs. By establishing a clear and formalized SLAs, the company will be able to determine the measurable Key Performance Indicators (KPI) like "*On-Time Delivery Rates*" and “*Order Cycle Time,” which* also make them easier for the company to be regularly monitored.

Currently, to refer to SLAs, X’s LLC manually calculates the date of work order release and the date of arrival time limit, which is stated in the contract. Despite efforts to incorporate logistics, the company faces challenges with late deliveries. Remarkably, the average of late deliveries in 2023 is 11%, which has not shown any depletion since 2022. The lack of formalized SLAs in X’s LLC has led to inconsistencies in service delivery, while working with manual processes takes more time. Without formalized agreements, there is a heightened risk of miscommunication and unmet service expectations, which can damage the company's reputation and lead to customer dissatisfaction (Trienekens et al., 2004). This inconsistency also poses a challenge internally, as the company faces unclear performance benchmarks or service delivery protocols to adhere to, which can result in inefficiencies and a decline in service quality.

Recognizing these challenges, formalizing SLAs is needed to ensure measurable performance and service consistency. Formalizing SLAs aligns with the company’s commitment to leveraging technology for operational excellence. By establishing clear and formalized SLAs, the company is able to determine measurable and relevant KPIs. Moreover, it eases for the company to monitor the KPIs regularly.

To address this issue, this research proposes an approach to formalized SLAs by leveraging PM techniques. SLAs are traditionally supported by a restricted set of attributes, one of which includes system availability. There are opportunities, however, to expand the number of attributes captured as part of the SLAs, allowing more customized and personalized services. Through the availability of enterprise systems, it is possible to gather the time period data. It is considered the use of PM to explore case duration within a logistic company. The utilization of PM will examine the discovered processes through data-driven reality. It is able to uncover the delays, hidden inefficiencies, and bottlenecks. Therefore, using PM to formulate SLAs facilitates continuous monitoring due to the measurable performance indicator (Peoples, Tariq, Moore, Zoualfaghari, & Reeves, 2021).

The study builds on prior work that has demonstrated the applicability of PM in the logistics domain. The software Apromore, as a leading tool in PM, holds significant potential to contribute to this research. Its advanced PM capabilities enable the extraction, analysis, and improvement of business processes directly from event logs, providing a deep understanding of actual operational workflows. Apromore's visual analytics and interactive process maps offer an intuitive means for exploring process variations and understanding their impacts on service levels, facilitating the development of a more standardized and realistic SLAs framework (Drakoulogkonas & Apostolou, 2021). Leveraging Apromore's Fuzzy Miner helps to discover the basic control flow and gain an initial high-level understanding. Fuzzy Miner has the capacity to handle complex, real-life event logs by abstracting and simplifying process maps. This capability is crucial for extracting meaningful insights from the intricate and voluminous data typically found in logistics operations. Hereinafter, additional PM analysis is needed, such as time analysis and bottleneck analysis (MAGER, 2013).

In this study, the SLA is specifically related to the work order fulfillment business process, ensuring that all steps from order creation to delivery are clearly defined and measured. It is assumed that the vehicle is always available, utilizing a special company-owned fleet database, which simplifies logistics planning and reduces delays related to fleet management. The process does not involve a warehousing component, as goods are always ready and stored at the customer's warehouse, thereby streamlining operations and minimizing lead times. Each case within this study involves only one delivery to a single destination, focusing on the efficiency and accuracy of individual deliveries to enhance overall service performance.

This research aims to propose a formalized SLAs framework by harnessing the power of PM. It seeks to answer critical questions such as how PM can be leveraged to create formalized SLAs in the logistics industry and what effects these standardized SLAs have on the overall quality and reliability of logistic services. This approach sheds light on the feasibility of the proposed standardization and illustrates the tangible impacts on service delivery efficiency and customer satisfaction.

The study is anchored in the theoretical underpinnings of business process management and service quality. These frameworks will guide the analysis of PM data and the formulation of a standardized SLAs model. The research will bridge these theories with real-world practices, contributing to the academic discourse on process optimization and service management. It will enhance the understanding of SLAs standardization's role in improving logistics operations and provide a replicable framework for service improvement through PM. These findings can potentially influence the company's policy-making and strategic decisions.

1.2 Problem Statement

In the rapidly evolving logistics industry, SLAs play a crucial role in defining the standards and expectations for service delivery between logistics companies and their customers. However, the management and formalization of these agreements pose significant challenges due to the complexity of logistics operations, the variety of services offered, and the dynamic nature of supply chain demands. The absence of formalized SLAs in X's LLC causes inconsistent service, leading to varying service quality levels. This inconsistency may result in customer dissatisfaction and damage the company's reputation. The unformalized SLAs provide unclear benchmarks for KPIs. Without them, it becomes challenging to objectively assess service performance, identify areas for improvement, or hold parties accountable for their commitments.

Furthermore, the absence of a standardized method for monitoring and evaluating the performance against SLAs complicates enforcing these agreements and identifying areas for improvement. However, there is a lack of research on how PM can be effectively utilized to standardize SLAs, particularly in the logistics industry, where the diversity of processes and the need for customization pose additional challenges.

Focusing on a case study within a logistic company, this study aims to provide practical insights and recommendations that can lead to more effective and formalized SLAs practices, ultimately improving service delivery and customer satisfaction in the logistics industry.

Based on the research background above, the problem statements are stated in the following points:

1.2.1 What are the SLAs formulated and formalized through PM analysis?

1.2.2 How do the formalized SLAs establish a clear benchmark for the company's KPIs?

1.3 Research Objective

The proposal of formalized SLAs using PM analyzes the time perspective of the processes. The formalized SLAs would be valuable for the company to develop relevant, measurable KPIs such as "*On-Time Delivery Rates*" and "*Order Cycle Time*." They enable the company to identify deviations quickly, pinpoint the root cause, and take corrective action, ensuring SLA targets are consistently met. This movement helps to increase service delivery and customer satisfaction.

1.4 Research Novelty

The research novelty in formalizing the SLAs in a logistics company, especially with previously unstandardized SLAs, is introducing a formalized framework to enhance operational efficiency, customer satisfaction, and consistency of service delivery. This approach leverages PM techniques to analyze and optimize the SLAs formalization process, ensuring it aligns with customer requirements and service capabilities. By moving from ad hoc to standardized SLAs assignments, the company can achieve a more systematic, transparent, and efficient service allocation, leading to improved service quality and customer trust.

1.5 Research Contribution

1.5.1 Theoretical Contribution

The research offers several theoretical contributions to the fields of service management, PM, and logistics. These contributions are pivotal in advancing academic knowledge and understanding of how technology-driven methodologies can enhance service delivery frameworks in logistics and beyond.

1.5.2 Practical Contribution

These theoretical contributions not only enrich academic understanding in these areas but also provide practical insights for X's LLC, including the benchmark of measurable performance and enhancing their service delivery, which could increase their customer satisfaction.

1.6 Research Limitation

The scope of the problem is limited to, along with assumptions as follows:

1. This research focuses on the land logistics business process (work order process).
2. The data input for PM is the event log data of the selected process activity recorded from the Fleet Integrated and Order Application (FIONA) in the company's enterprise system. It is only included the data of the company-owned fleet, which all activities use the same fleet from start to finish the work order.
3. The event log data originated from Branch A (one of X's LLC branches with the biggest revenue and strategic location.
4. The data is taken for the time period of January 01st, 2023 – December 29th, 2023.

1.7 Writing Systematics

This research is organized into several chapters with the aim of facilitating the flow of the thinking process. The systematics in writing this thesis will be described as follows:

CHAPTER 1 INTRODUCTION

This chapter explains the research background, problem statement, research objectives and contribution, research limitations, and research writing systematics.

CHAPTER 2 LITERATURE STUDY

This chapter explains related theories that are appropriate to the research topic and describes the concepts used as a research basis.

CHAPTER 3 RESEARCH METHODOLOGY

This chapter discusses the systematic steps for carrying out research, starting from field studies, identification of problem formulation, literature study, designing research instruments, data collection and preparation, PM analysis, time analysis, and SLAs proposal.

CHAPTER 4 RESULT AND DISCUSSION

This chapter discusses data collection and processing in accordance with the research design. The data is processed for quantitative analysis using the PM method. The analysis's results are used as the basis for the proposed SLAs and KPIs.

CHAPTER 5 CONCLUSION AND FUTURE WORKS

This chapter contains conclusions by the desired research objectives and suggestions for improvements for further research.

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CHAPTER 2
LITERATURE REVIEW AND THEORETICAL BACKGROUND

2.1 State of The Art

Several previous studies that are used as references in the current research are explained in Table 2 1, Table 2 2, and Table 2 3 below:

Table 2 1 Previous study about SLAs (1)

No	Title	Authors	Research Objectives	Research Method
1	Aggregation of Service Level Agreements in the Context of Business Processes	Tobias Unger, Frank Leymann, Stephanie Mauchart, Thorsten Scheibler	To define a method enabling service providers to aggregate individual service SLAs into a comprehensive business process SLAs, ensuring defined non-functional properties are met.	The paper proposes a two-part framework consisting of a formal SLAs model and a concept for aggregating SLAs with customizable algorithms.
2	Analysis of Customer Fulfilment with Process Mining: A Case Study in a Telecommunication Company	Mahendrawathi ER, Hanim Maria Astuti, Ayu Nastitia	To discover the typical customer fulfilment process, assess the completion rate of customer fulfilments, identify necessary components for the process, and determine lead times for various types of customer requests.	The study employed PM tools (Disco and PROM) on event logs extracted from the company's CRM systems to analyze the customer fulfilment process.
3	Business Process Mining: An Industrial Application	W.M.P. van der Aalst, H.A. Reijers, A.J.M.M. Weijters, B.F. van Dongen, A.K. Alves de Medeiros, M. Song, H.M.W. Verbeek	To apply PM techniques on real-life data from the Dutch National Public Works Department to uncover actual process flows, identify bottlenecks	Utilized the ProM framework to analyze invoice processing data from a provincial office, focusing on process, organizational, and case perspectives through various PM techniques.

Table 2 2 Previous study about SLAs (2)

No	Title	Authors	Research Objectives	Research Method
3	Business Process Mining: An Industrial Application	W.M.P. van der Aalst, H.A. Reijers, A.J.M.M. Weijters, B.F. van Dongen, A.K. Alves de Medeiros, M. Song, H.M.W. Verbeek	To apply PM techniques on real-life data from the Dutch National Public Works Department to uncover actual process flows, identify bottlenecks, and suggest improvements.	Utilized the ProM framework to analyze invoice processing data from a provincial office, focusing on process, organizational, and case perspectives through various PM techniques.
4	Mining Business Contracts for Service Exceptions	Xibin Gao, Munindar P. Singh, Pankaj Mehra	To develop an information extraction approach for discovering service exceptions in business contracts, facilitating better management and analysis of service engagements.	Unsupervised information extraction utilizing linguistic patterns and parsing to identify service exception phrases from business contracts.
5	Modelling Service Level Agreements for Business Process Outsourcing Services	Adela del-Río-Ortega, Antonio Manuel Gutiérrez, Amador Durán, Manuel Resinas, Antonio Ruiz-Cortés	To develop a formal methodology for modeling SLAs within the context of BPO services, facilitating the automation of performance monitoring and process configuration.	The approach combines existing computational SLAs models with business process and performance indicator modeling techniques to create a comprehensive framework.
6	Deriving Business Processes with Service Level Agreements from Early Requirements	Ganna Frankova, Magali Séguran, Florian Gilcher, Slim Trabelsi, Jörg Dörflinger, Marco Aiello	To develop a methodology for designing service-based business processes integrated with SLAs from early requirements, focusing on quality of execution and security.	The methodology utilizes the Secure Tropos formalism for early requirements analysis, followed by transformations and reasoning to generate Secure BPEL processes and SLAs.

Table 2 3 Previous study about SLAs (3)

No	Title	Authors	Research Objectives	Research Method
7	Service Level Agreement based on Process map	Holger	To create structured, customer-centric SLAs for IT services by integrating SLAs with business process maping concepts.	Utilizing workflow concepts in the design and content of SLAs to make them understandable and actionable for both customers and providers.
8	Analysis of Service Level Agreements Using Process Mining Techniques	Christian Mager	To demonstrate the application of PM in analyzing the time perspective of SLA-defined processes and to identify time-related bottlenecks.	The paper describes utilizing PM techniques for the creation of an integrated process map that allows a fine-grained investigation of the time perspective in processes.
9	Using Process Mining to Formalise Service Level Agreement (SLA) Allocation	Cathryn Peoples, Zeeshan Tariq, Adrian Moore, Mohammad Zoualfaghari, Andrew Reeves	To standardize the SLAs assignment process using PM techniques, enhancing service allocation and customer satisfaction.	Applying PM to analyze and improve the SLAs assignment process, focusing on customer classification, interaction, and service allocation.

Unger, Leymann, Mauchart, & Scheibler (2008) conduct research focusing on the aggregation of SLAs within Business Process Execution Language (BPEL) processes. It introduces a formal model for representing SLAs, including Service Level Parameters (SLPs) and a single Service Level Objective (SLO). The findings emphasize the need for a flexible framework to define, aggregate, and manage SLAs effectively, highlighting the potential for process improvement and standardized service quality in business processes.

Mahendrawathi, Astuti, and Nastiti (2015) utilized PM to analyze customer fulfillment processes in a telecommunications company. They aimed to discover the typical customer fulfillment business process, assess the completion rate, identify necessary components, and evaluate order fulfillment time. The analysis revealed a low completion rate (8%) and identified 18 typical business variants. These findings suggest significant room for process improvement and highlight the importance of addressing data integration issues in PM implementations.

W. M.P. van der Aalst et al. (2007) applied PM techniques to the invoice processing activities of a Dutch National Public Works Department, focusing on process, organizational, and case perspectives. Utilizing the ProM framework, the study analyzed over 14,000 invoices to uncover the actual process flow, organizational interactions, and case-handling specifics. Findings revealed a main process flow with sequential activities, alternative paths, and loops, particularly highlighting the frequent occurrence of reevaluation loops in case processing. This analysis provided insights into the efficiency and areas for improvement within the department's invoice handling process.

Gao, Singh, & Mehra (2012) introduce Contract Miner, a tool for extracting service exceptions from business contracts. Utilizing an unsupervised information extraction approach, Contract Miner analyzes contracts to identify exceptions at the phrase level, supporting the development of a taxonomy of business terms and aiding in the modeling and analyzing of service engagements. The study demonstrates Contract Miner's precision and recall effectiveness through evaluation over a corpus of manually annotated contracts, highlighting its potential to enhance the management and analysis of contractual agreements in business settings.

Alter (2015) explores modeling SLAs for Business Process Outsourcing (BPO) services, integrating computational SLAs frameworks with business process and performance indicators modeling. It identifies four critical elements for SLAs formalization: business process description, Service Level Objectives (SLOs), penalties and rewards, and metrics for guarantees. By applying this model to real BPO SLAs, the study validates its approach, highlighting the potential to enhance SLA management in BPO services through structured modeling and analysis. This work improves the automation, monitoring, and management of SLAs in BPO services, addressing the need for process-aware information systems that can adapt to varied SLA conditions and client requirements.

Frankova et al. (2011) present a methodology for modeling SLAs in the context of BPO services, integrating computational SLA frameworks with business process maping and performance indicators. The study emphasizes the importance of four elements: detailed business process descriptions, clear Service Level Objectives (SLOs), defined penalties and rewards, and specific metrics for guaranteeing SLAs compliance. By applying this model to actual BPO scenarios, the research validates its effectiveness, demonstrating its potential to streamline SLAs management, enhance automation, and improve monitoring and compliance within BPO services. This contributes to developing adaptable information systems capable of handling diverse SLAs requirements and client needs.

Schmidt (2000) advocates for a novel approach to SLAs specification, integrating workflow concepts into IT service agreements. This methodology emphasizes customer-centric and constructive SLA designs, leveraging workflow management principles to delineate clear, operational service and management interactions. By grounding SLAs in the customer's business processes, the approach aims to produce non-ambiguous, actionable contracts, enhancing the manageability and quality of IT services from the customer's perspective. The findings suggest this integration facilitates a more systematic and effective SLAs design, promising improved cooperation between service providers and customers.

MAGER (2013) introduces a novel approach for analyzing SLAs using PM techniques, focusing on the time perspective crucial for SLAs compliance. It demonstrates how PM can extend beyond simple SLAs monitoring by providing a detailed analysis of executed processes from a service provider's perspective. This includes identifying time-related bottlenecks and enabling continuous quality improvement in IT services, aligning with ITIL claims. The study highlights the significance of integrating process map discovery and time perspective analysis for better SLAs management and process optimization.

Peoples et al. (2021) introduce a novel approach to SLAs assignment, leveraging PM to better understand and standardize the process of allocating SLAs to customers. It highlights the development of an SLAs generation process that assigns SLAs based on collected customer knowledge, offering insights from both customer and system perspectives. The study successfully discovered the underlying business process of SLAs assignment using the Heuristic Miner, aiming to standardize the process based on event logs generated while collecting highly variable customer requirements. This methodology is a foundation for future conformance analysis and process enhancement, promising to improve the precision in SLAs assignments.

PM has increasingly become a pivotal tool in many research, particularly for understanding and optimizing complex processes across various domains. Its application in standardizing SLAs represents a significant innovation, especially in industries like logistics where SLAs standardization has been lacking. Organizations can systematically analyze and refine their service delivery processes by leveraging PM. This approach ensures compliance with SLAs and enhances operational efficiency and customer satisfaction, marking a transformative step towards more reliable and transparent service management practices.

Following the above recent studies on the standardization of SLAs and the use of PM, it is known that PM has been applied in several sectors, including IT and Internet service providers. In several previous studies, SLAs standardization with PM has not been applied to logistics companies. Through this research, we will try to apply it to logistics companies. This research is aimed at standardizing SLAs in logistics companies, which is essential because companies don't have standards, so performance can not be measured quantitatively, so it refers to SLAs standards, which are calculated manually.

2.2 Theoretical background

2.2.1 Service Level Agreements (SLAs)

One of the determined Quality of Service (QoS) is SLAs. SLAs are a formal contract between service providers and their customers that define the level of service expected from the service provider. SLAs are critical for establishing clear expectations and benchmarks for service delivery, ensuring that both parties have a common understanding of service standards, deliverables, performance metrics, and consequences for service level breaches (Chandana et al., 2017). SLAs contract usually state that the consumer only pays for the resources and services used according to the negotiated requirements at a given price (MAGER, 2013).

According to Ahmad et al. (2020), Chandana et al. (2017), and Unger et al. (2008), the metrics that are covered in SLAs, including the list of services and resources, service level parameters, performance targets, monitoring and reporting mechanisms, problem management, and penalties or bonuses in case of under or over-performance. SLAs need to be comprehensive, measurable, and achievable, with clear definitions of service parameters to avoid ambiguity and ensure enforceability. The key components of SLAs in logistics are as follows:

1. Scope of Services:
    - Clearly defines the range of logistics services covered under the SLA, such as transportation, warehousing, inventory management, order fulfillment, and distribution.
2. Performance Metrics:
    - On-Time Delivery Rate: The percentage of orders delivered within the agreed time frame.
    - Order Cycle Time: The total time taken from receiving an order to fulfilling it.
    - Order Accuracy: The accuracy of order fulfillment, including correct items, quantities, and documentation.
    - Inventory Accuracy: The accuracy of inventory records compared to physical stock.
    - Pick and Pack Accuracy: The correctness of items picked and packed for shipment.
3. Response Times:
    - Order Processing Time: The time taken to process an order from receipt to dispatch.
    - Customer Service Response Time: The time taken to respond to customer inquiries or issues.
    - Incident Resolution Time: The time taken to resolve logistics-related issues or disruptions.
4. Availability and Uptime:
    - System Availability: The expected uptime of logistics management systems, such as warehouse management systems (WMS) or transportation management systems (TMS).
    - Operational Hours: The hours during which logistics services will be available and operational.
5. Quality Standards:
    - Handling Procedures: Standards for the handling, packaging, and transportation of goods to ensure their safety and integrity.
    - Compliance: Adherence to regulatory and industry standards, such as safety regulations, environmental standards, and customs requirements.
6. Cost and Compensation:
    - Pricing Structure: The cost of logistics services and any pricing models (e.g., per shipment, per mile, per hour).
    - Penalties and Incentives: Penalties for failing to meet SLA targets and incentives for exceeding performance expectations.
7. Monitoring and Reporting:
    - Performance Reporting: Regular reports on SLA performance, including key metrics and any incidents or deviations.
    - Review Meetings: Scheduled meetings to review SLA performance, discuss improvements, and address any issues.
8. Responsibilities and Roles:
    - Service Provider Responsibilities: The duties and obligations of the logistics service provider.

- Customer Responsibilities: The expectations and responsibilities of the customer, such as providing accurate order information and timely communication.

The alignment of SLAs with business objectives and customer expectations is also highlighted as a critical factor in successfully implementing SLAs. Adopting the SLAs also act as a KPI (Knowledge Performance Index) for the internal services that reflect back to the company performance and users experiences (Ahmad et al., 2020). SLAs standardization aims to keep the QoS reasonable (Schmidt, 2000). SLAs are particularly important in Business Process Outsourcing (BPO) scenarios, where an enterprise reduces the focus on its core business and outsources supporting processes to other companies specializing in this area, for example, a logistics company (Unger et al., 2008).

2.2.2 Logistics

The logistics industry has undergone significant transformations in recent years, driven by the increasing demand for efficient and reliable supply chain management. As the global economy continues to evolve, logistics companies face both challenges and opportunities in their quest for transformation and upgrading (Zhang, 2018).

One critical aspect of logistics management is the development and implementation of effective SLAs between logistics providers and their clients. Logistic Service Providers play a crucial role in coordinating and optimizing logistics operations on behalf of various participants, with the goal of improving efficiency and profitability for all stakeholders (Wang et al., 2015). To achieve these objectives, a formalized SLAs can serve as a valuable tool to align expectations, set performance standards, and facilitate effective collaboration.

However, the development of such agreements can be a complex and time-consuming process, often relying on manual data analysis and subjective assessments. In this context, the application of PM techniques can provide a more systematic and data-driven approach to the development and management of service level agreements in the logistics industry.

2.2.2.1 Business Process in Logistics

The business process in logistics is a complex and multifaceted endeavor, as it requires the coordination of various activities and resources. Company must carefully plan, implement, and control the flow of raw materials, in-process inventory, and finished goods, as well as the associated information, from the point of origin to the point of consumption. This process includes activities such as transportation, warehousing, inventory management, and order processing, all of which must be optimized to achieve the desired level of efficiency and responsiveness.

This research will focus on the data originated from X's LLC database especially for the land logistic operational of work order fulfilment using company-owned fleet. Its business process is shown in Figure 2 1.

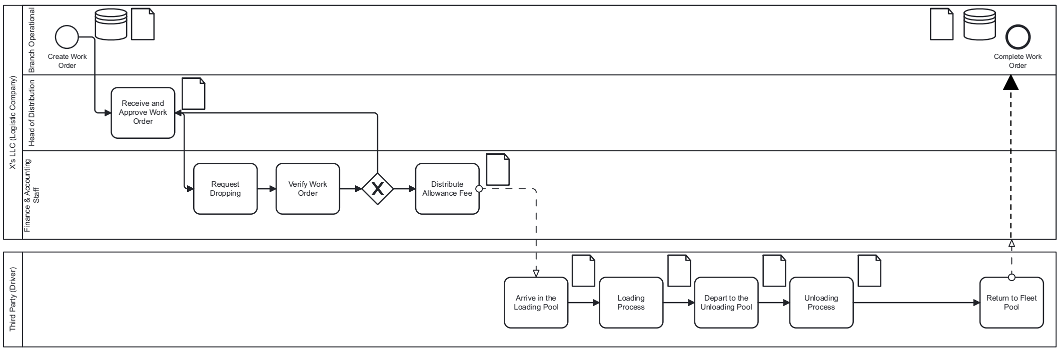

Figure 2 1 Business Process of Work Order Fulfilment

2.2.2.2 Performance in Logistics

The performance of a logistics system is crucial in determining the overall success of a business. Company that fail to develop and optimize their logistics efficiency often find themselves at a competitive disadvantage. Logistics strategy should be considered an integral component of a company's overall business strategy, as it can provide a significant competitive advantage. Empirical studies have shown that logistics can create value for customers by reducing the cost of the logistics network while maintaining or improving agreed levels of service (Soni & Gupta, 2020).

Academicians and practitioners alike recognize the importance of logistics services and operating systems as an integral part of a firm's overall marketing strategy. Consequently, there is a need for an ongoing, interactive review of actual logistics system performance, so that company can achieve operating systems improvements as well as select and implement the most profitable corporate strategies.

2.2.2.3 Key Performance Indicators and Service Level Agreements in Logistics

In order to effectively measure and manage the performance of a logistics system, key performance indicators must be established. These KPIs should be aligned with the firm's overall business objectives and customer requirements. Some common KPIs in logistics include delivery time, on-time delivery, order fill rate, and logistics cost as a percentage of total cost.

Closely related to KPIs are SLA, which define the expected level of service to be provided by the logistics service provider. The responsibility for setting and managing these SLAs typically falls on the shoulders of the logistics manager, who must work closely with the service provider to ensure that the agreed-upon levels of service are consistently met.

2.2.2.4 Implementing Service Level Agreements in Logistics

Implementing effective SLAs in logistics is a critical task that requires careful planning and collaboration between the firm and the logistics service provider. The logistics manager must clearly define the expected level of service, establish appropriate KPIs, and put in place mechanisms for monitoring and evaluating the provider's performance. This may involve the use of advanced technologies, such as real-time tracking systems, to provide visibility into the logistics process and facilitate the measurement of KPIs.

Company that wish to sustain a competitive advantage through logistics must adopt a "logistics learning capability," which enables them to continuously improve and reinvent their logistics strategies and processes.

2.2.3 Business Process

Business processes are structured activities that take one or more inputs to establish output that is valued by customers (Aguilar-Savén, 2004). These processes are fundamental to any organization's operations, as they involve the systematic coordination of people, technologies, and practices to achieve business objectives. By the above definition, business processes act as a baseline for achieving operational performance.

The optimization of business processes is crucial for enhancing efficiency, reducing costs, and improving product quality/service and customer satisfaction. As organizations strive to adapt to changing market conditions and technological advancements, the continuous improvement and innovation of business processes become essential for maintaining competitiveness and achieving sustainable growth. Hence, they should be continuously analyzed, monitored, and improved consistently to achieve efficient organizational performance and business value. To do this, companies should remove inefficiencies and bottlenecks and ensure compliance issues are improved within processes (Aguilar-Savén, 2004).

2.2.3.1 Business Process Management (BPM)

BPM is the discipline that combines knowledge from information technology and knowledge from management sciences and applies it to operational business processes. It consists of a combination of methods, techniques, and tools to optimize organizational performance (Sujanawati, ER, & Wibowo, 2021). In recent years, BPM has received considerable attention due to its potential for significantly increasing productivity and saving costs (Wil M. P. van der Aalst, 2013).

BPM can be seen as an extension of Workflow Management (WFM). WFM primarily focuses on automating business processes, whereas BPM has a broader scope: from process automation and process analysis to operations management and the organization of work. On the one hand, BPM aims to improve operational business processes, possibly without the use of new technologies. For example, by modeling and analyzing a business process using simulation, management may get ideas on reducing costs while improving service levels.

BPM consists of Process Instance, Customer, Actor, Object, Activity, Event, Decision Point, and Outcome. The BPM consists of several stages that guide the management of business processes, namely the BPM life cycle. The BPM life cycle starts with Process Identification, where the process will be identified, and process architecture is developed. Then, process discovery is carried out by determining the process in more detail. The next stage is Process Analysis to identify and assess the problems and opportunities for process improvement, followed by Process Redesign to identify the changes in resolving the problem. After that, the new process will be implemented at the implementation stage, where it will be monitored and managed in Process Monitoring (Sujanawati et al., 2021). The BPM life cycle of BPM is shown in Figure 2 2.

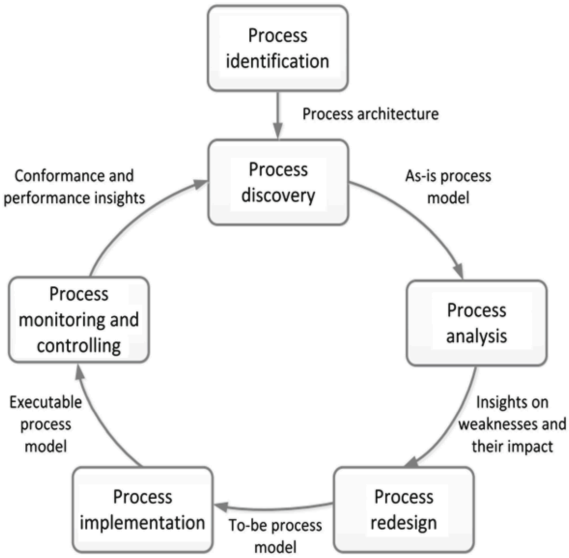

Figure 2 2 BPM Life Cycle (Mining, 1993).

2.2.4 Process Mining (PM)

PM is a cutting-edge field that sits at the intersection of data science and process management as illustrated in Figure 2 3. It offers profound insights into how business processes actually operate within an organization. PM is relatively young research discipline and it focuses on extracting knowledge from data generated and stored in organization's information system (Rojas, Munoz-Gama, Sepúlveda, & Capurro, 2016).

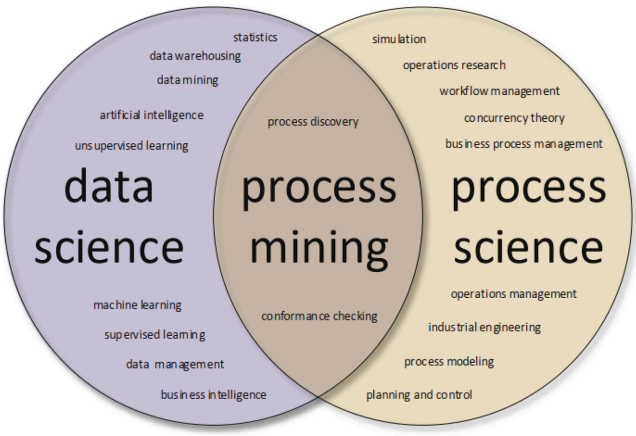

Figure 2 3 Process Mining = data science ∩ process science (Aalst, 2022).

PM aims to improve operational processes through the systematic use of event log data by identifying bottlenecks, anticipating and diagnosing performance, and supporting the automation or removal Non-Value-Adding (NVA) activity. PM techniques can be backward-looking or forward-looking. They can be used in any operational process including manufacturing, logistics, finance, sales, procurement, etc (Aalst, 2022).

PM involves three key aspects: discovery, conformance, and enhancement, as shown in Figure 2 4 (Rojas et al., 2016).

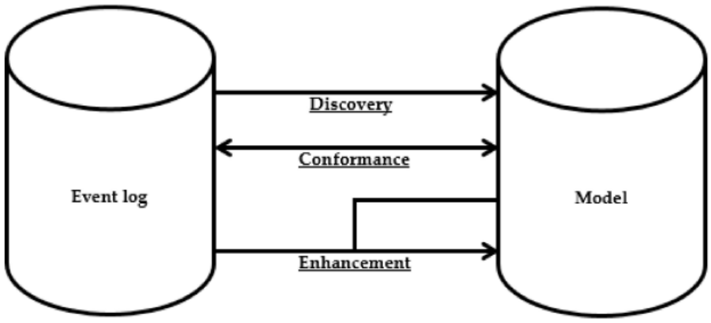

Figure 2 4 Process Mining Types (Drakoulogkonas & Apostolou, 2021)

Conversely, conformance involves comparing the discovered process maps with pre-existing models or norms to identify deviations, non-compliance, and opportunities for improvement. Enhancement focuses on improving existing processes based on the insights gained from discovery and conformance checks, aiming to optimize performance, reduce costs, and improve customer satisfaction. Those three aspects are more detailed in the below explanation:

A. Discovery

Process discovery is defined as the act of gathering information about an existing process and organizing it in terms of an "As-Is" process map. This technique takes an event log and automatically constructs a process map. The primary goal of this technique is to create transparency and the acquisition of current "As-Is" process knowledge, it highlights routing probabilities, determines the most frequent common path in the process and discovers common and uncommon behaviour of cases by displaying different process flow variants (Drakoulogkonas & Apostolou, 2021).

Process discovery can potentially offer a greater level of flexibility when mining complex and infrequent process patterns. Process discovery is used when the procedures are informal or even if the company has well-documented procedures, the reality shows differently (W. Van Der Aalst, 2012). For example, using the α-algorithm. α-Algorithm is a typical example of a process discovery, which clarifies the basic idea behind many PM algorithms. There are many ways of representing a process map using notation/languages like BPMN, EPK, YAWL, or Petri-Nets. The α algorithm discovers a Petri net (Aalst, 2022).

B. Conformance

The aim of this technique is to define an apriori model and compare it with reality from event logs to detect and diagnose any discrepancies and commonalities between an apriori model and the event log. Four quality dimensions for comparing model and log are typically considered: fitness, simplicity, precision, and generalization. Conformance checking helps to discover the number of cases that do not conform to the apriori model. It explains where the processes deviate themselves and shows process flow violations; it supports measuring the severity of their occurrences and finding process loops, if any. And measure the overall level of compliance performance (Aalst, 2022).

Different quality dimensions are used to evaluate how well a process map describes the observed behavior. Conformance checking is particularly important to check the quality of the reproduced process map compared to the event log (W. Van Der Aalst, 2012).

C. Enhancement

It is a crucial phase focusing on improving existing business processes based on insights from analyzing event logs. This stage goes beyond merely identifying and visualizing how processes are currently performed (discovery) and how they conform to predetermined models or standards (conformance). Instead, enhancement actively seeks to modify and optimize the business processes to achieve greater efficiency, reduce costs, increase customer satisfaction, and ensure compliance with regulations. Through the application of advanced analytics, PM tools can suggest specific changes to process flows, resource allocations, and decision points. These suggestions are informed by patterns, bottlenecks, and inefficiencies identified during the analysis of real process data. Moreover, enhancement can involve predictive modeling and simulation techniques to forecast the outcomes of proposed changes before implementation, reducing the risk of unintended consequences. By closing the loop from discovery through enhancement, PM enables organizations to iteratively refine their operations, align processes with strategic objectives, and adapt to changing business environments (W. Van Der Aalst, 2012).

The studies arranged by Mager (2013) and Peoples et al. (2021) have explored the role of PM in standardizing SLAs, particularly in complex service environments like logistics and IT services. PM techniques enable organizations to analyze and improve their business processes based on data from event logs, providing insights into actual process performance. This data-driven approach to understanding service delivery processes can significantly enhance the accuracy and relevance of SLAs, making them more reflective of real-world capabilities and expectations.

Many industries consider PM a tool to monitor and improve to facilitate operational excellence (Mamudu, Bandara, Leemans, & Wynn, 2023). PM tools, like Apromore, ProM, and Celonis, offer a range of functionalities that support these activities, from automatic process discovery and advanced analytics to predictive modeling and process simulation. These tools can analyze data across different dimensions, including time, cost, and quality, allowing organizations to prioritize improvements based on their strategic goals.

Numerous enterprise information systems have recently recorded business events in so-called event logs. It draws from computational intelligence, data mining (DM), and BPM (Mamudu et al., 2023). PM aims to construct model automation explaining the behavior observed in the event log. The event logs will be used to discover process, control, data, organizational, and social structures (W. M.P. van der Aalst et al., 2007). The event log is assumed to be able to record the events (in which event refers to an activity), performer, originator, and timestamp and are totally ordered. The event log is shown in Figure 2 5.

Case id	Activity id	Originator	Timestamp
Case 1	Activity *A*	John	9-3-2004:15.01
Case 2	Activity *A*	John	9-3-2004:15.12
Case 3	Activity *A*	Sue	9-3-2004:16.03
Case 3	Activity *B*	Carol	9-3-2004:16.07
Case 1	Activity *B*	Mike	9-3-2004:18.25
Case 1	Activity *C*	John	10-3-2004:9.23
Case 2	Activity *C*	Mike	10-3-2004:10.34
Case 4	Activity *A*	Sue	10-3-2004:10.35
Case 2	Activity *B*	John	10-3-2004:12.34
Case 2	Activity *D*	Pete	10-3-2004:12.50
Case 5	Activity *A*	Sue	10-3-2004:13.05
Case 4	Activity *C*	Carol	11-3-2004:10.12
Case 1	Activity *D*	Pete	11-3-2004:10.14
Case 3	Activity *C*	Sue	11-3-2004:10.44
Case 3	Activity *D*	Pete	11-3-2004:11.03
Case 4	Activity *B*	Sue	14-3-2004:11.18
Case 5	Activity *E*	Clare	17-3-2004:12.22
Case 5	Activity *D*	Clare	18-3-2004:14.34
Case 4	Activity *D*	Pete	19-3-2004:15.56

Figure 2 5 An Event Log (W. M.P. van der Aalst et al., 2007).

2.2.4.1 Event Log

The event log is a number of events extracted in the context of a process that indicates which activity has happened at a specific time. The quality of the event log determines the result; an event log with low quality could lead to the fault interpretation model (Marin-Castro & Tello-Leal, 2021). To conduct a PM analysis, an event log should contain a minimum of enough information that is activity and timestamp (Suriadi, Andrews, ter Hofstede, & Wynn, 2017). According to (Mining, 1993), the characteristics of an event log are conceived in Figure 2 6:

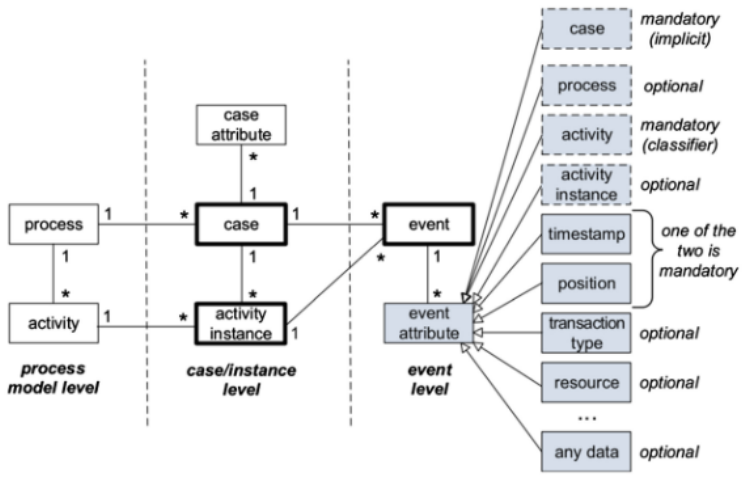

Figure 2 6 The Event Log's Class Diagram (Mining, 1993)

1. Case ID

It is a unique identifier that identifies one single case of the process. (usually combination of purchase order number and purchase order line-item number). It influences the process scope as it solely determines where the process starts and where it ends for each case. Therefore, it is mandatory to know for every event which case it refers to so that the PM tool can compare several executions of the process to one another.

2. Activity name
   Corresponds to the name of the process event performed in the ERP system. Data scientists assign activity names at the time of event log creation. The aim is to describe the reference of each activity within a single row of an event log.

3. Timestamp
   The third most important prerequisite is having at least one timestamp column that indicates at what date and time each activity took place. Timestamp for PM follows a particular representational format: dd/mm/yyyy, hh/mm/ss. With the help of timestamps, performed activities are ordered in the sequence they took place. This supports identifying delays between activities, and bottlenecks in the process, and measuring compliance performance.

2.2.4.2 Fuzzy Miner Algorithm

PM, a data-driven approach, has gained significant attention as it enables the extraction of valuable insights from event logs recorded in the ERP (Mohammadi, 2019). One of the key tasks in PM is the discovery of process maps, which involves transforming event logs into comprehensive process maps. An automated process discovery technique takes as input an event log and produces as output a process map that captures the behavior of the log in a representative way.

The Fuzzy Miner algorithm plays a crucial role in this transformation, as it provides a flexible and appropriate approach to discover process maps from event logs (Sun et al., 2021). The Fuzzy Miner algorithm is particularly useful when dealing with event logs that exhibit infrequent behaviors or complex relationships between activities (Djenouri et al., 2018). Unlike traditional process discovery algorithms that focus solely on the control-flow perspective, the Fuzzy Miner algorithm incorporates the relationship between infrequent behaviors and data conditions, allowing for a more comprehensive understanding of the underlying process (Premchaiswadi et al., 2018).

Apromore's Fuzzy Miner algorithm simplifies the process discovery by leveraging event logs to generate simplified process maps that highlight the most important and connected events (Dumas, La Rosa, Mendling, & Reijers, 2018). It is a moderately significant mining algorithm that handles challenging and unstructured data when it facilitates the cooperative streamlining of the process map, as confirmed by an event log (Vidyapeetham et al., 2017). Fuzzy Miner reduces the complexity of the model by removing less important relationships and actions with thresholds. The process maps are further abstracted by the clustering of highly connected activities into macro activities.

The end product is a dependency graph, in which dependencies are represented by edges with characteristics like length and frequency, and activities are represented by nodes (Dumas et al., 2018). Dependency graphs are a popular technique to visualize event logs. A dependency graph (also known as a directly-follows graph) is a graph where each node represents one event class (i.e., a task) and each arc represents a “directly follows” relation. An arc exists between two event classes A and B if there is at least one trace in which B comes immediately after A. The arcs in a dependency graph may be annotated with an integer indicating the number of times that B directly follows A (hereby called the absolute frequency). Figure 2 7 shows an event log (left) and a corresponding dependency graph (right). It observed that the arc from task a to task b has an absolute frequency of 60. This is because the event log has six distinct traces where b occurs immediately before a and each of these distinct traces occurs 10 times.

10 × a,b,c,g,e,h
10 × a,b,c,f,g,h
10 × a,b,d,g,e,h
10 × a,b,d,e,g,h
10 × a,b,e,c,g,h
10 × a,b,e,d,g,h
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10 × a,d,b,f,g,h

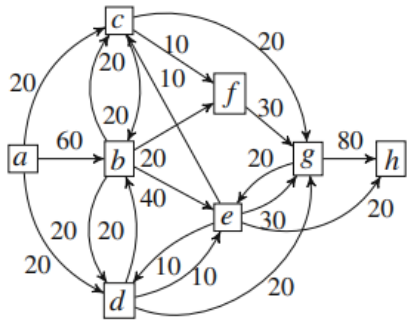

Figure 2 7 An *Event Log* and Comparable Dependency Graph (Dumas et al., 2018)

A dependency graph is a visual representation of the dependencies between activities in a process. In PM, it helps to understand how activities are related to each other, the frequency of their occurrences, and the strength of their relationships. According to the Dumas et al. (2018) the Fuzzy Miner algorithm works in several steps to generate the dependency graph:

1. Significance and Correlation Metrics: Fuzzy Miner calculates two main metrics for each pair of activities, that are significance (how frequently activities occur) and correlation (how strongly activities are related).
2. Thresholding/Rule Mining: this step helps in understanding the dependencies and correlations between activities. Activities and dependencies that do not meet certain significance and correlation thresholds are filtered out, providing a basis for simplification and abstraction.
3. Clustering: Highly correlated activities are grouped together to form macro activities, further simplifying the models.

Owing to their simplicity, dependency graphs is so-called Fuzzy Miner plugin of Apromore. All these tools provide visual cues to enhance the readability of dependency graphs. Besides their simplicity, one of the most appealing features of dependency graphs is that they are susceptible to abstraction operations (Günther & Van Der Aalst, 2007b). In this context, abstraction refers to removing a subset of the nodes or arcs in a dependency graph in order to obtain a smaller dependency graph of a given event log. For example, PM tools allow us to remove the most infrequent nodes or arcs from a dependency graph in order to obtain a simpler map that is easier to understand. Abstraction is an indispensable feature when we want to explore a real-life event log, as illustrated in Figure 2 8. The discovered models are often "spaghetti-like", showing all details without distinguishing what is important and what is not (Günther & Van Der Aalst, 2007b).

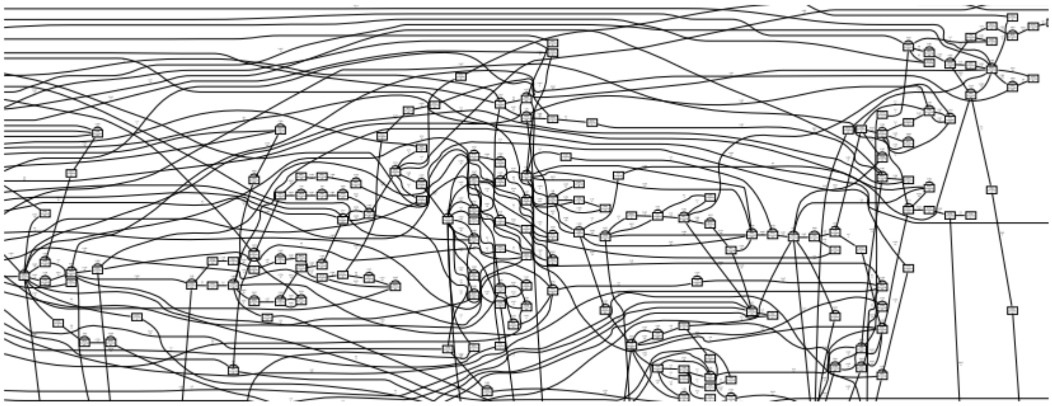

Figure 2 8 A Typical "Spaghetti" Process map (Günther & Van Der Aalst, 2007b)

2.2.5 Apromore

PM aims to exploit event data meaningfully, e.g., to improve processes, provide insights, recommend actions, find bottlenecks, record policy violations, and prevent problems. PM techniques can extract knowledge from information systems' event logs. There are tools that can be used for the execution of operations related to PM, one of which is Apromore.

Apromore (Advanced Process Map REpository) is a web-based advanced process analytics platform developed by the BPM community under an open-source initiative (Verenich, Stanislav, Rosa, & Maggi, 2018). Apromore has been implemented as an open-source SaaS (Software-as-a-Service) (La Rosa et al., 2011). Some of the advantages of Apromore are that it (i) has an easily extensible framework, where new plugins can be added to a system of advanced business process analytics capabilities; (ii) provides a shared workspace of logs and models; (iii) includes a multi-log animation and flow comparison. (Drakoulogkonas & Apostolou, 2021).

Through advanced PM techniques, Apromore is designed to provide deep insights into business processes. It is equipped with *Fuzzy Miner,* which is particularly proficient at handling complex and noisy data sets. This tool is best for simplifying process maps, making it easier to analyze and understand, especially in environments where data may be incomplete or ambiguous (Hong & Lee, 2008). Fuzzy Mining processes these logs to construct an initial model that captures the main activities and their connections, filtering out infrequent behaviors and noise. Fuzzy Mining allows users to adjust parameters like edge cut-offs and node simplification to highlight the paths and nodes that are crucial for the service being analyzed (Günther & Van Der Aalst, 2007a).

This selective focus helps identify key performance indicators (KPIs) that are essential for the SLAs. With a clear process map, it becomes easier to identify specific KPIs such as on-time delivery rate. For instance, if the model reveals that certain tasks consistently take longer than expected, these can be flagged for the SLAs violations (MAGER, 2013).

2.2.6 Enterprise Resource Planning (ERP)

ERP is comprehensive software that integrates all company information system data (Susanto, 2010). ERP allows sharing of real-time information, and the software has main applications in the form of modules such as Supply Chain Management (SCM), Customer Relationship Management (CRM), Product Lifecycle Management (PLM), e-procurement, and Financial Management (Barthorpe et al., 2004).

ERP that is implemented effectively provides several benefits for companies such as (i) can increase profits from appropriate response times and delivery times, (ii) becomes the basis for decision-making regarding additional resources to improve service quality, and (iii) provides related information actual operational service conditions (Wallace & Kremzar, 2001).

2.2.6.1 Fleet Integrated and Order Application (FIONA)

FIONA is an application used to improve monitoring functions starting from orders, distribution, fleet, data quality, analysis, and reporting of fleet and order information management. It is a development application of the FIONA application. Application FIONA can make it easier for companies to control and monitor existing fleets so that the company can immediately make decisions about managing the fleet.

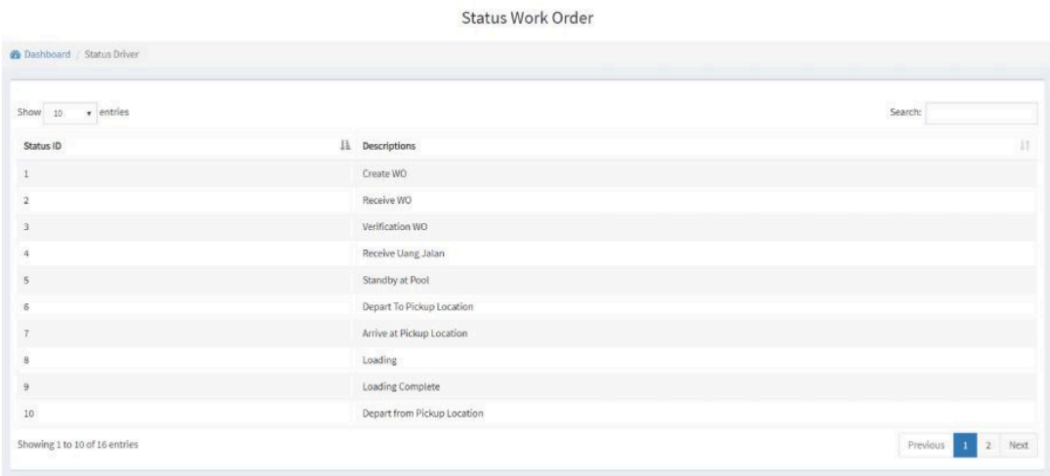

Figure 2 9 Work Order Status on FIONA

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CHAPTER 3
RESEARCH METHODOLOGY

3.1 Flowchart

This section will detail the methodology of this thesis. Figure 3 1 and Figure 3 2 below provide visual representations of the methodology.

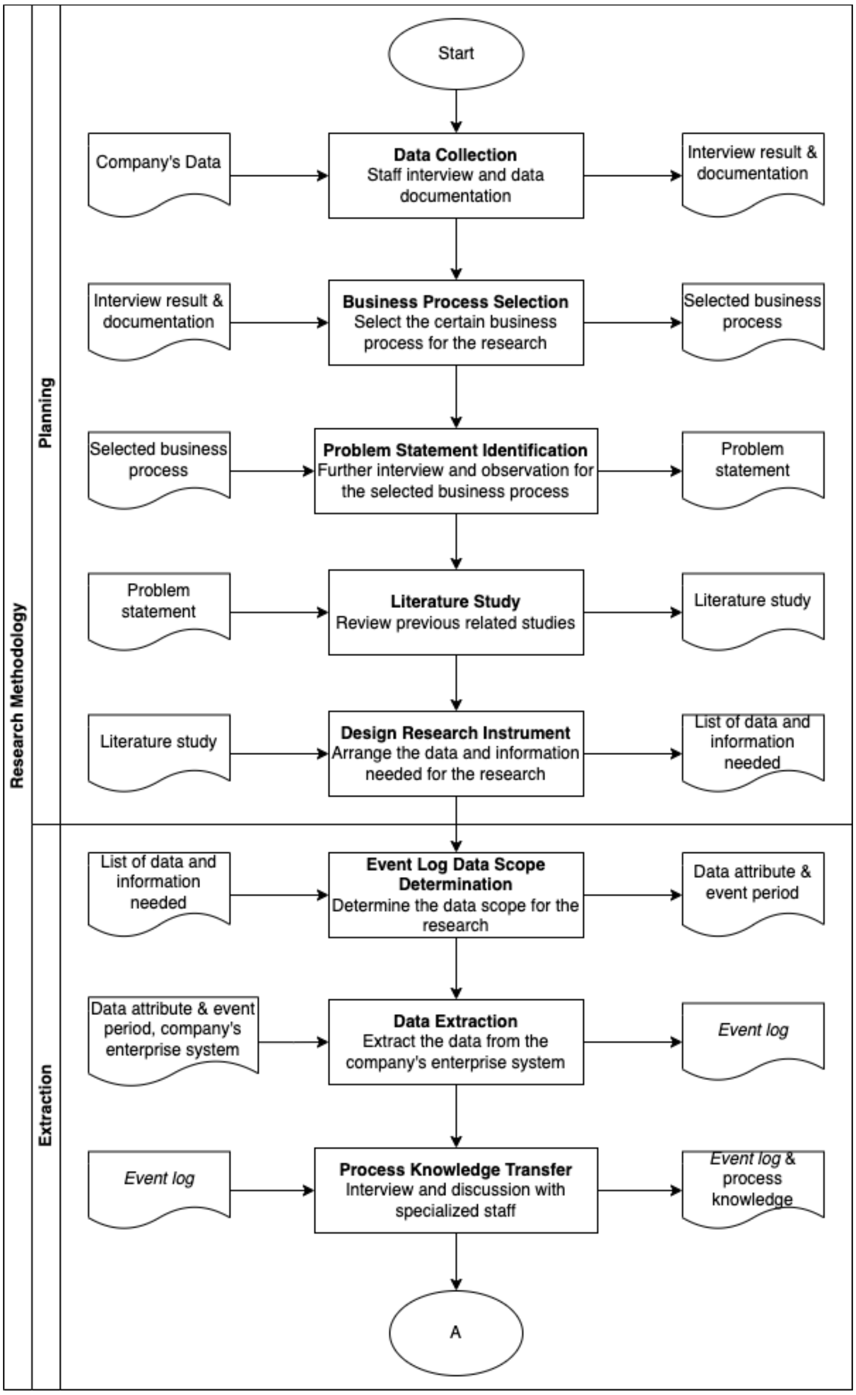

Figure 3 1 Research Methodology (1)

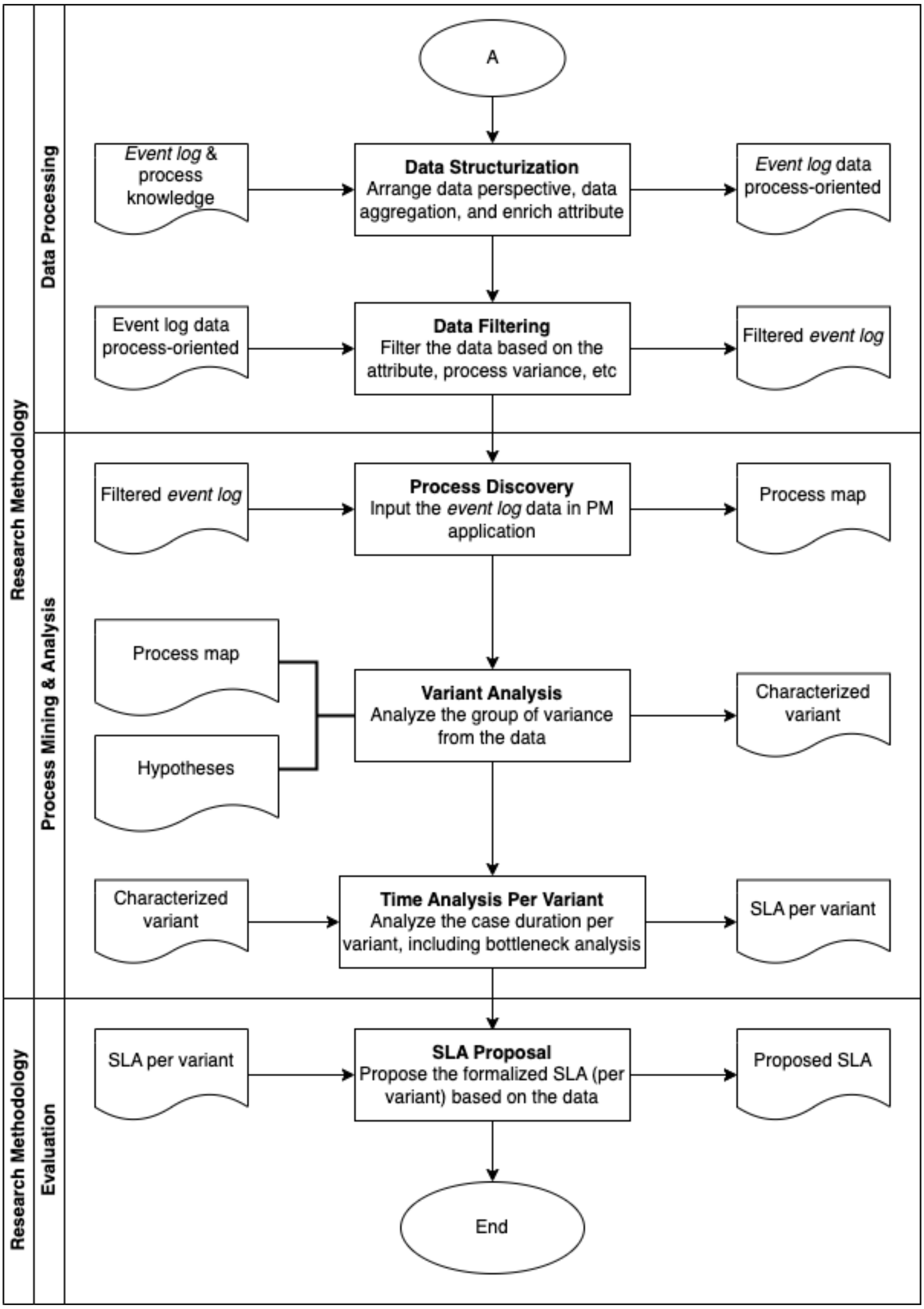

Figure 3 2 Research Methodology (2)

3.2 Research Methodology

Before initiating this research, the author had already seized permission from X's LLC to collect and publish data. This permission was granted from the integrity pact authorization between the two parties. There are several conditions should be followed:

1. The company's identity must be concealed.
2. Raw data obtained from the company, including discussion outcomes, should not be attached (unless only mentioned).
3. Standard Operating Procedures (SOPs) and data processing results are permissible for display.

This research will use the PM project methodology (PM^2) approach (Van Eck, Lu, Leemans, & Van Der Aalst, 2015) with the following description.

3.2.1 Planning

This stage aims to design the research instrument by examining the company's current problem. The input of this stage is the organization's business processes. The output of this stage is the list of data and information needed for the research (Van Eck et al., 2015). Several activities are carried out in the planning stage, as follows.

3.2.1.1 Data Collection

PM research will use a business process within the organization that will be analyzed and improved. Before choosing a business process, collecting data related to the organization that will be the research object is necessary. In the research, the organization that will be studied is a logistics company (X's LLC). Data is collected through subject interviews. The interview is covered by examining the current situation and the problems X's LLC faces. X's LLC operates in multiple services, including warehouse management, logistics, and supply chain management. The interview involves the operational logistics team, IT team, and HR team. The observation is also conducted on:

a. Standard Operating Procedures (SOPs): Documented procedures detailing the standard method of conducting logistics operations within X's LLC.
b. Observing the current business process related to SLAs management.
c. Document analysis in relation to SLAs management, such as contract and Stock Transport Order (STO)
d. Insights from Discussions: Qualitative data is obtained through discussions with the strategic experts, specifically the operation team and IT team, offering a deeper understanding or perspectives on the operational processes and systems.

3.2.1.2 Business Process Selection

The interview has led to a more informed and precise decision-making process. The results of the interview with X's LLC made clear how important it is to standardize SLAs. The business process of "Work Order (WO) Fulfillment Process" has choosen for this study. To formulate SLAs, the WO activity of land transportation is extracted to generate an event log from the FIONA application.

The selected business process includes a series of activity explained in Table 3 1 and Table 3 2.

Table 3 1 Activity Definition (1)

No	Activities	Category	Description
1	Create Work Order	Processing time	The duration that is taken for the logistic staff to access the "Create Work Order (WO)" page, enter the necessary data, and complete the creation of the WO after gathering information related to Internal Order, delivery notification and fleet used.
		Waiting time	The time to wait the branch manager to approve the created WO is appropriate (WO will be successfully published when the branch manager has approved) and the created WO is received by the accounting department.
2	Receive Work Order	Processing time	The operational time for the branch manager to approve the WO.
		Waiting time	The idle time to wait the branch manager to verify the WO.
3	Verify Work Order	Processing time	The time that is taken for the accounting staff to re-check and approve the WO.
		Waiting time	The waiting time to transfer the allowance to the driver.
4	Receive Allowance	Processing time	The operational time for the accounting staff to prepare the fee, double check with the WO, and hand over the allowance fee to the driver
		Waiting time	The idle time of waiting the driver's heading to the loading pool after received the allowance fee.
5	Depart to The Loading Pool	Processing time	The time required to get into the loading pool.
		Waiting time	The idle time to wait the products being loaded.
6	Arrive in The Loading Pool	Processing time	The time required to check and assess fleet compatibility, waybill delivery, and other documents.
		Waiting time	The waiting time (queue) to wait the loading process begin.
7	Loading Process	Processing time	The time required to check the products, load the products from the warehouse into the fleet.
		Waiting time	The idle time of re-checking product compatibility, quantity, etc.

Table 3 2 Activity Definition (2)

No	Activities	Category	Description
8	Loading Process Done	Processing time	The time required to complete the loading documentations and get ready to depart.
		Waiting time	The idle time to wait the fleet ready to depart to the unloading pool.
9	Depart from The Loading Pool	Processing time	The time required to get into the unloading pool (started from the loading pool).
		Waiting time	The idle time to wait the products being unloaded.
10	Arrive in The Unloading Pool	Processing time	The time required to check and assess fleet compatibility, product conformity, waybill delivery, and other documents.
		Waiting time	The waiting time (queue) to wait the unloading process begin.
11	Unloading Process	Processing time	The time required to unloaded the products from the fleet to the unloading warehouse.
		Waiting time	The idle time of documentation during unloading process.
12	Unloading Process Done	Processing time	The time required to complete the documentation and get ready to leave.
		Waiting time	The idle time to wait the fleet ready to leave.
13	Return to The Pool	Processing time	The time required to get into the fleet pool (started from the unloading pool).
		Waiting time	The idle time to park the fleet.
14	Arrive in the Pool	Processing time	The time required to check the fleet condition as per stated before its used.
		Waiting time	The waiting time to complete the documentations.
15	Complete Work Order	Processing time	The time required to complete the WO, document checklist, and fleet checklist.

3.2.1.3 Problem Statement Identification

After selecting the business process as the research object, the next step is formulating research objectives and problem statements. This stage is carried out by further analyzing the birth certificate application process with additional interviews and observations of the business process. The information gathered provides a strong groundwork for defending the issue that has been highlighted and creates the basis for a thorough review of the literature. This method guarantees a thorough comprehension and contextual examination of the problem at hand.

3.2.1.4 Literature Study

A literature review is prescribed to gather knowledge from recent related studies and the theoretical study underlying the identified issue. This is accomplished by exploring books, journals, and previous studies. Literature studies were carried out to understand the concepts, methodology, and theories that form the basis of this final assignment research. It is hoped that the literature study can help answer the problem formulation in this PM research.

3.2.1.5 Design of Research Instruments

The design of the research instrument was carried out to obtain more data needed for this research. This stage is done by compiling data requirements and a list of questions for further interviews during the research process. This is important because every insight gained from PM exploration must be confirmed with the specialized subject as the process owner.

3.2.2 Extraction

The data extraction aims to extract event log data and process maps. The input from this stage is the problem formulation and information system that was determined during the preparation stage. The output of the extraction stage is event log data (Van Eck et al., 2015). There are several activities in the extraction stage, with details as follows.

3.2.2.1 Event Log Data Scope Determination

Before taking data, the scope of the data needs to be determined first. There are four things that must be considered when determining the scope of data. First, it is important to determine the granularity of the event log to be captured. It is important to pay attention to how much detail the data will be used or if parts of the data were not taken. Second, the data period to be extracted. The event log data period is important to obtain additional context and information before PM begins. Third, what attributes will be extracted from the event log data, and the last is how the correlation between the data will be extracted. These four things are important for determining the scope of event log data so that the results of PM exploration have clear context and information (van Eck, Lu, Leemans, & van der Aalst, 2015).

FIONA is one of the enterprise systems in X's LLC that will be used in this research. The necessity of extracting the work order data has been determined due to the talks and the examination of business operations. Alongside determining the specific data required for extraction, paying attention to several key aspects is essential. These are:

a. Granularity: The level of detail in the data.
b. Data Period: This refers to the timeframe of the data, specifically from January 2023 to December 2023.
c. Downloadable Attributes: This includes the activity code, a description of the activity, and the timestamps.
d. Activity Correlations: Understanding the relationships and interconnections between different activities.

3.2.2.2 Data Extraction

After the scope of the event log data is determined, the next step is to extract data. The required data for the selected business process is taken from the company's enterprise system. The extracted data will be combined into a collection of activities and cases recorded in the information system. The format of the extracted data is generally a CSV (comma-separated value) file, which can be accessed via the Microsoft Excel program.

3.2.2.3 Process Knowledge Transfer

Process knowledge transfer activities can be carried out simultaneously with event data extraction. The event log data obtained needs to be accompanied by knowledge regarding the process and purpose of each data attribute. This knowledge is usually known by the process owner or business expert of the business process being studied. This activity aims to facilitate the next stage of data processing. Process knowledge transfer can be done with interviews and brainstorming sessions. Process-related knowledge can be in the form of process documentation or previously created process maps (van Eck, Lu, Leemans, & van der Aalst, 2015).

3.2.3 Data Processing

The main goal of the data processing stage is to generate event logs in several perspectives and convert them into an optimal PM process. This stage uses event logs and process maps to filter event logs that will be used in the analysis and mining stages (Van Eck et al., 2015). Several activities are carried out at the data processing stage.

3.2.3.1 Data Structurization

Each case in the event log obtained usually describes a specific activity recorded in the system. The data consists of cases and activity classes. When combined, a case can consist of several activities that will become a process instance. Therefore, the first data structuring carried out is creating a perspective by converting event log data into a process based on the case. Perspective creation is done by looking at the objectives of the analysis (Van Eck et al., 2015).

Then, it must aggregate the activities that occur. Activity aggregation reduces data complexity. Aggregation can be done using two approaches: the is-a and part-of approaches. The is-a approach considers several different activities of the same type to be one type of activity while maintaining the total occurrence of that activity. The part-of approach considers several activities into one larger activity (Van Eck et al., 2015).

After carrying out the aggregation, the next step is to enrich the event log by adding several relevant attributes for analysis. Adding attributes can be done by considering additional activity from the event log data or external data. Attributes are added according to the needs and objectives of the analysis (Van Eck et al., 2015)

In this research, the work order fulfillment of event log data will be sorted based on each case ID, activity, and activity timestamp (timestamp). Other attributes that can help analysis are also added, such as resource attributes, which refer to actors working on the process. Aggregation is also done by seeing whether activities can be combined into other activities to reduce data complexity.

The enterprise system of X's LLC houses an extensive array of data. Nevertheless, the focus of the extraction process is specifically on data related to the work order process, encompassing every stage from its initiation to its completion. The work order activity log is detailed below and shown in Figure 3 3:

a. No_DA, stands for the work order application number that will be used to identify the Case ID
b. Commodity, indicates the product's/commodity's transported.
c. StatusID, characterize the stage of activity sequence.
d. Status, identifies the certain activities involved.
e. UpdateAt, the start timestamp.
f. FinishAt, the end timestamp.
g. UpdateBy, the resources incharge whether to create, excecute, or verified.

No_DA	Commodity	StatusI	Status	updateAt	finishAt	updateBy
WO.1007.01.23.12615	ELEKTRONIK	1	Work Order Dibuat	03/01/2023 07.24.26	03/01/2023 07.27.21	Admin DKI
WO.1007.01.23.12615	ELEKTRONIK	2	Work Order Diterima	03/01/2023 07.29.25	03/01/2023 07.35.34	840412055115
WO.1007.01.23.12615	ELEKTRONIK	3	Verifikasi Work Order	03/01/2023 07.37.39	03/01/2023 07.40.41	Admin DKI
WO.1007.01.23.12615	ELEKTRONIK	4	Uang Jalan Diterima	03/01/2023 07.43.52	03/01/2023 07.45.40	Admin DKI
WO.1007.01.23.12615	ELEKTRONIK	7	Tiba Dilokasi Pemuatan	03/01/2023 13.10.57	03/01/2023 13.11.02	840412055115
WO.1007.01.23.12615	ELEKTRONIK	8	Proses Pemuatan	03/01/2023 15.11.02	03/01/2023 17.11.07	840412055115
WO.1007.01.23.12615	ELEKTRONIK	9	Selesai Proses Pemuatan	03/01/2023 17.14.35	03/01/2023 17.16.34	840412055115
WO.1007.01.23.12615	ELEKTRONIK	10	Berangkat dari Lokasi Pemuatan	03/01/2023 17.20.39	04/01/2023 06.13.39	840412055115

Figure 3 3 Work Order Activity Log

3.2.3.2 Data Filtering

Filtering is often carried out at the data processing stage to reduce complexity and focus on analyzing certain parts. This process is usually repeated in PM iterations to gain multiple perspectives. Data filtering can be done by eliminating or taking attributes with certain values, taking data with certain variants, or looking at data that does not comply with the process rules (Van Eck et al., 2015).

3.2.4 PM and Analysis

At this stage, further analysis will be carried out to answer the problem statements. The input from this stage is the processed event log. The output of this stage is findings that answer the research problem statement (Van Eck et al., 2015). The PM stages are carried out using the Apromore application. As explained in Chapter 2, several PM activities are usually carried out as follows.

3.2.4.1 Process Discovery

Using the event log as input, the PM stage generally begins by finding the actual process of the business process. This activity will produce a process map based on the fact data entered (Van Eck et al., 2015). A process map diagram will be displayed using the Apromore application. The found process map can be used for further analysis.

3.2.4.2 Variant Analysis

As part of the SLAs proposal, herewith a variant analysis is conducted to which they have been identified as belonging to. X's LLC serve multiple customers with multiple products/commodities in which they will have specific SLAs. The product classification in this research is based on the product/commodity category, with an assumption that different commodities often require specific treatments that can significantly impact the SLAs. In the SLAs recommendation, we take into account the SLAs of each segments.

It recognized that assumptions may be being made on the basis of the product classification. It base these assumptions to consider these products classification following GPC (Global Product Classification), is a GS1 standard 2023 that classifies products by grouping them into segments. The standard helps those who do business globally to group products in the same way, everywhere in the world. This results in information that is clear and is immediately understandable. The categories in GPC are based on the main characteristics of the products and their relationships with other products. Thereby the product classification for this research is shown in Table 3 3.**Error! Reference source not found.**

Table 3 3 Product Classification (GS1, 2023)

No	Products/Commodities	Segment
1	Food	Food/Beverage
2	Groceries	Food/Beverage
3	Rice	Food/Beverage
4	Chemicals	Healthcare
5	Pharmaceutical Drugs	Healthcare
6	Electronic	Electrical Supplies
7	Battery	Electrical Supplies
8	Pipe	Building products
9	Iron	Building products
10	Tin	Building products

3.2.4.3 Time Analysis by Segment

This stage is employed to analyze these variants for time-based performance metrics, such as average completion time, maximum and minimum execution times, and any deviations from expected timelines. The critical step involves comparing these metrics against the time specifications set forth in the SLAs, such as the maximum allowable time for process completion or specific milestones within the process.

3.2.5 Evaluation Stage

The evaluation stage aims to link PM findings with ideas for improving processes to achieve research objectives. The input from this stage is the process map, performance, and findings related to process suitability from the previous stage. The output of the evaluation stage is process improvement ideas and new problem formulations (Van Eck et al., 2015).

3.2.5.1 SLAs Proposal

At this final stage, based on the insights derived from PM, the methodology proceeds to the formulation of SLAs proposals. These proposals are grounded in the empirical evidence gathered from the process analysis, ensuring that the SLAs are realistic, achievable, and tailored to the specific dynamics of the business processes under investigation. The proposed SLAs include key performance indicators (KPIs), such as on-time delivery rate and order cycle time, which are critical for measuring and managing process performance and compliance.

CHAPTER 4
RESULT & DISCUSSION

This research aims to analyze the time perspective of the processes. The formalized SLAs would be valuable for the X's LLC to develop relevant measurable KPIs. By applying PM^2, the research intends to analyze the existing service processes within the logistics company. This evaluation will pinpoint areas where the proposed SLAs could better govern and enhance performance.

This chapter is organized to acknowledge the problem statements as stated in Section 1.2. The broad stages of this research include Planning, Extraction, Data Processing, PM Analysis, and Evaluation as organized in Figure 3 1 and Figure 3 2. To formalize the SLAs through PM analysis, it began by planning data collection and problem identification. Hereafter, extracting the event log data from the FIONA application. This data included are unique identifier, timestamps, activities, and resources involved in each logistics process. Using Apromore, it then mapped out the actual process map of these operations, highlighting the typical process sequence, variations, and case durations. Variant analysis is carried out to classify products into segments as they show similarity in product handling and transportation. By calculating the total of the average case duration in each segments, we proposed the SLAs, creating precise, measurable, and realistic service level targets.

To establish a clear benchmark for the company's KPIs through the formalized SLAs, we integrated the formalized SLAs into the company's performance management framework. First, we translated the SLAs into specific, measurable KPIs that reflect the critical aspects of service delivery, such as "*on-time delivery rates*" and "*order cycle time*". It also established baseline values for each KPIs based on historical performance data obtained from the PM analysis. By setting these baseline values, we provided a reference point against which future performance could be measured. This approach ensured that the formalized SLAs served as a clear, consistent benchmark for evaluating and improving the company's operational performance.

4.1 Overview Data Collection

4.1.1 Lists of Data Required

PM analysis to discover processes and analyze the time perspective of the processes are aimed to calculate the SLAs and propose the formalized SLAs requires several data as listed in Table 4 1. The process discovery stage requires event log data from the FIONA application which records all logistics operational activities. After discovering the actual process, compliance with the applicable SOP will be checked, so a logistics operational SOP document is needed. Besides, other documents are also needed, such as the organizational structure and parties involved as supporting data. Additional product/commodity variety information is used for the variant analysis to propose SLAs.

Table 4 1 Lists of Data Required

No.	Data	Description
1	Event log data of logistic operational through FIONA	The FIONA event log records every activity and transaction that occurs within the X's LLC enterprise system, especially those related to the logistic operation process. The FIONA application is used to access real-time monitoring functions starting from orders, distribution, fleet, data quality, analysis and reporting of fleet and order management information. Data extracted from FIONA comes with attributes case ID, activity name, timestamp, resource and product category. This data will be analyzed by the PM application to discover the actual process. Analyzing this data helps in determining SLAs based on time perspective analysis and identifying bottlenecks to reduce SLAs violations (MAGER, 2013).
2	SOP of Logistic Operational	The Standar Operating Procedure for the logistic's operational determines every single step that must be followed to ensure the logistic's operational funcionate as planned and in-control. This SOP includes the planning, implementation, and management of the logistics operation. The SOP aims to ensure everything is effective and efficient. The SOP was needed to check the actual compliance of the processes.
3	Organizational Structure and Involved Parties	An organizational structure characterize clear roles and responsibilities within the company. This clarity ensures that each part is handled by the right people, whether it's data collection, analysis, or implementation of new processes. A formal structure helps streamline decision-making processes by clearly identifying who has the authority to make decisions at various levels. This is important for timely approvals and modifications of the SLAs based on PM insights.
4	Research method of (Peoples et al., 2021)	In analyzing the time perspective processes and proposing the SLAs, there will be a commodity classification as referred to the research Peoples et. al., (2021) with an assumption that each commodity will belong to their specific delivery and handling needs. In the SLAs proposal, we take into account each classification that helps to automatically distinguish between them. The details of this are presented in this paper.

4.1.2 Event Log Data Scope Result

At this stage, the event log data scope will be retrieved. Determining this scope is important to know the limitations of the PM analysis that will be carried out. The scope of the data taken is adjusted to the problem statement that will be answered in this research. There are four aspects to consider to determine the scope of the data taken, namely: (1) data granularity, (2) data period, (3) data attributes, and (4) correlation between the data taken.

The granularity of the event log is taken from the data recorded in the FIONA application, depending on the level of activity carried out. The Work Order (WO) activity of land transportation is extracted to generate an Event Log from the FIONA application. This scope is taken by considering the main activities related to SLAs formulation.

The data period taken is 1 year. It covers the handling of work orders from January 2023 to December 2023. During this period, the process ran according to standards, and there were no major changes to the SOP or within X’s LLC management.

There are 6 attributes that will be retrieved, namely the case ID number, which describes the unique number for each work order, the name of the activity being carried out, the timestamp when the activity started, the timestamp when the activity was completed, the resource that carried out the work, and the product/commodity category sent. Details of each attribute taken will be explained in the next section. Each attribute is interconnected with each others, where each work order can be identified through one case ID. Each case ID can have several activities carried out from the beginning to the end of the business process. Each captured activity has start timestamp and end timestamp data indicating the duration of the activity. Each activity also has an actor who works on that activity. Additional attributes related to product category will be useful for the variant analysis stage, where differences in product delivery may involve different treatments.

4.1.3 Data Extraction Result

After determining the scope of data to be analyzed, the next step is extracting event log data from the FIONA application. Data extraction was carried out with the help of X's LLC IT team. Data collection was carried out on January 8th 2024. The data taken was in the form of a Microsoft Excel file related to each submitted application case, along with the required attributes. Hereinafter, the data is preprocessed/structured and converted into a CSV file before being uploaded into Apromore.

4.1.4 Data Structurization Result

After obtaining the raw event log data from X's LLC, the next step is preprocessing the data. Data preprocessing prepares data for analysis through Apromore. Figure 4 1 shows an example of event log data provided by X's LLC.

No_DA	Commodity	StatusI	Status	updateAt	finishAt	updateBy
WO.1007.01.23.12615	ELEKTRONIK	1	Work Order Dibuat	03/01/2023 07.24.26	03/01/2023 07.27.21	Admin DKI
WO.1007.01.23.12615	ELEKTRONIK	2	Work Order Diterima	03/01/2023 07.29.25	03/01/2023 07.35.34	840412055115
WO.1007.01.23.12615	ELEKTRONIK	3	Verifikasi Work Order	03/01/2023 07.37.39	03/01/2023 07.40.41	Admin DKI
WO.1007.01.23.12615	ELEKTRONIK	4	Uang Jalan Diterima	03/01/2023 07.43.52	03/01/2023 07.45.40	Admin DKI
WO.1007.01.23.12615	ELEKTRONIK	7	Tiba Dilokasi Pemuatan	03/01/2023 13.10.57	03/01/2023 13.11.02	840412055115
WO.1007.01.23.12615	ELEKTRONIK	8	Proses Pemuatan	03/01/2023 15.11.02	03/01/2023 17.11.07	840412055115
WO.1007.01.23.12615	ELEKTRONIK	9	Selesai Proses Pemuatan	03/01/2023 17.14.35	03/01/2023 17.16.34	840412055115
WO.1007.01.23.12615	ELEKTRONIK	10	Berangkat dari Lokasi Pemuatan	03/01/2023 17.20.39	04/01/2023 06.13.39	840412055115

Figure 4 1 Raw Event Log

Based on the data provided, data processing is required before PM analysis. The following is the process carried out to prepare event log data so that it compatibles the structure required by the Apromore:

4.1.4.1 Attribute Identification

The next step is to identify the attributes required for PM analysis. Table 4 2 is the attribute used in event log data.

Table 4 2 Event Log Attributes

No	Column Name	Description
1	No_DA	Unique code for each work order
2	Commodity	Type of product/commodity
3	Status ID	A number of activities
4	Status	A series of activities of each case
5	Update At	The initial time each activity starts
6	Finish At	Activity end time
7	Update By	Actor executing each activity
8	Company ID	Unique ID for certain company's branch

There are several columns that are removed from the raw event log data, such as the "Status ID" and "Company ID" columns because they are not the data/attributes needed for analysis. Figure 4 2 is an example of event log data with appropriate attributes.

No_DA	Commodity	Status	updateAt	finishAt	updateBy
WO.1007.01.23.12615	ELEKTRONIK	Work Order Dibuat	2023/01/03 07:24:26	2023/01/03 07:27:21	Admin DKI
WO.1007.01.23.12615	ELEKTRONIK	Work Order Diterima	2023/01/03 07:29:25	2023/01/03 07:35:34	840412055115
WO.1007.01.23.12615	ELEKTRONIK	Verifikasi Work Order	2023/01/03 07:37:39	2023/01/03 07:40:41	Admin DKI
WO.1007.01.23.12615	ELEKTRONIK	Uang Jalan Diterima	2023/01/03 07:43:52	2023/01/03 07:45:40	Admin DKI
WO.1007.01.23.12615	ELEKTRONIK	Tiba Dilokasi Pemuatan	2023/01/03 13:10:57	2023/01/03 13:11:02	840412055115
WO.1007.01.23.12615	ELEKTRONIK	Proses Pemuatan	2023/01/03 15:11:02	2023/01/03 17:11:07	840412055115
WO.1007.01.23.12615	ELEKTRONIK	Selesai Proses Pemuatan	2023/01/03 17:14:35	2023/01/03 17:16:34	840412055115
WO.1007.01.23.12615	ELEKTRONIK	Berangkat dari Lokasi Pemuatan	2023/01/03 17:20:39	2023/01/04 06:13:39	840412055115

Figure 4 2 Event Log Data with Appropriate Attributes

4.1.4.2 The Data Dupplication Removal

Before event log data is ready, it is necessary to eliminate duplicate data in each row. This is needed so that the process discovery analysis can be more accurate. Duplicate data is removed for each row and column via the Microsoft Excel feature.

4.2 Process Discovery

4.2.1 Process Map Visualization

In the process discovery stage in Apromore, the event log input will be visualized in the process map by the involvement of fuzzy miner algorithm. A process map, also known as a directly-follows graph (explained in Section 2.2.4.2), is a graph representation of the log that shows the activities of the process as nodes, and the sequential order linkages between the activities are shown by directed arcs connecting the nodes.

A process map is better to understand if the most common actions are shown as a horizontal line. When setting up the process map in Apromore, there are three possible layout options: User-defined backbone, Auto-discovered backbone, and Legacy left-to-right. The legacy left-to-right layout for process maps is best recommended because it standardizes the interpretation and clearly represents the sequence of events.

4.2.2 Abstraction Setting

The complexity of process map can be adjusted by increasing or decreasing the visualized nodes and arcs, namely abstraction. Abstraction is to set the nodes and arcs into the desired level. The nodes slider is set to 100%, Apromore will display all frequent nodes and do not remove any infrequent. Likewise, set the Arcs slider to 100%, then Apromore will display all the arcs between the current set of nodes. The Apromore's default values for the nodes and arcs sliders are 100% and 10%, respectively.

The process map can be abstracted by the case frequency or average duration. By using case frequency view, if the arcs or nodes slider is shifted towards the left (decreasing), more nodes with low case frequency will be removed from the process map. Otherwise, by using average duration view, if the arcs or nodes slider is shifted towards the right (increasing), more nodes with all average duration will be fully visualize from the process map.

4.2.2.1 Fuzzy Mining Application

To demonstrate how the Fuzzy Miner algorithm in Apromore works, the sample of the event log has provided in **Appendix 1**. This log includes activities as listed in Table 3 1 and Table 3 2. Upon loading this event log into Apromore, the Fuzzy Miner algorithm processes the data to calculate two key metrics for each event: significance and correlation. The sample logs are then applied to Apromore and resulted the process map as shown in Figure 4 3. The abstraction is set into 100% nodes and 100% arcs.

Figure 4 3 Example of The Process Map as a Result of Fuzzy Mining

Figure 4 3 shows the comprehensive representation of all the nodes and arcs, indicating a complete variant of the process. In BPM, a 100% representation means that every possible activity and transition within the process has been captured, leaving no part of the workflow undocumented. Nodes in a process map represent different activities or events within the process. Arcs are the directed lines connecting the nodes, representing the flow of the process from one activity to the next. Having a process map that shows 100% of nodes and arcs is invaluable for a comprehensive understanding of the process. This complete variant allows stakeholders to visualize every potential route the process may take, including rare or exceptional paths. This process map can be simplified by adjusting the arcs percentage into 10% (as per by default) and it will show the simplified map as shown in Figure 4 4. This visualization only show the most 10% of the overall cases, the another less significant variants are removed.

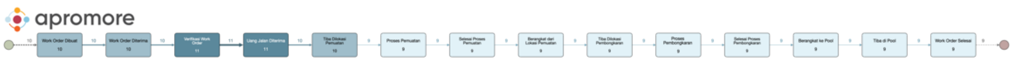

Figure 4 4 Example of The Default Process Map as a Result of Fuzzy Mining

This abstraction helps to focus on the critical parts of the process, making it easier to identify inefficiencies or bottlenecks. By interacting with this model in Apromore, we can drill down into specific activities or relationships, providing a clear, concise overview of the logistics operations while maintaining the flexibility to explore more detailed aspects as needed. This approach enables a more targeted and effective analysis, ultimately aiding in the improvement of service level agreements and overall process performance.

4.2.2.2 The Overall Process Map

The overall process map discovery of the event logs for this research is shown in Figure 4 5. The nodes slider is set to 100%, Apromore will display all frequent nodes and do not remove any infrequent. The Arcs slider is set to 100%, then Apromore will display all the arcs between the current set of nodes. The process map is illustrated in Figure 4 5 below.

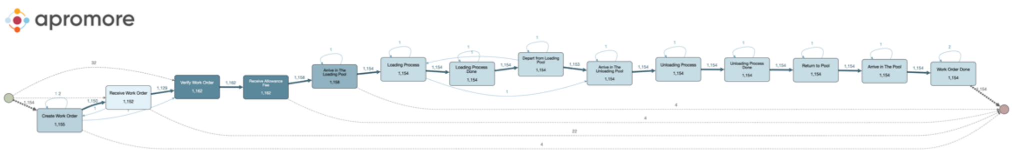

Figure 4 5 Overall Process Map with 100% Arcs

Figure 4 5 show a fairly complicated process map. This process maps are usually called “Spaghetti-like” process map. The spaghetti process map shows an uncontrolled process due to the large number of possible variations. A spaghetti-like process map will make the analysis more complicated. To facilitate analysis and obtain interesting findings, abstraction is carried out. One example of abstraction is to remove some activity flows that occur less frequently compared to other flows (van der Aalst W. M., 2016). Abstraction is done using Apromore’s arc abstraction feature, by setting the percentage of nodes and arcs.

Figure 4 6 and Figure 4 7 are an example of a process map with an 51% arc abstraction where the process map will only show 51% (more than half of the total cases) of the entire process flow that frequently occurs. Figure 4 6 shows the process map view by case frequency and Figure 4 7 shows the process map view by average duration. This abstraction is carried out to obtain the most representative flow of all cases in X's LLC operation.

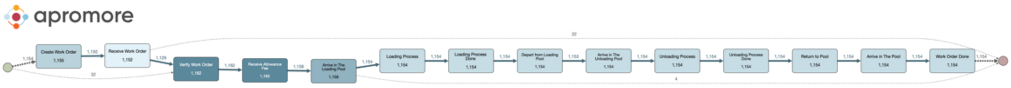

Figure 4 6 Overall Process map View by Case Frequency

Figure 4 7 Overall Process map View by Average Duration

Based on Figure 4 6 and Figure 4 7, they show which activity starts the case, and which activity ends the case. "*Work Order Created*" activity indicates the activity starts. This activity begins case work. “*Work Order Completed*” is the activity that ends the work. In general, these activities are in accordance with the SOP applied to X's LLC.

Figure 4 6 shows the the total case number of an activity has executed. This information is provided as a label on the activities/arcs, color of activities, and arcs’ thickness. The darker the blue color, the higher the number of times that activity has been observed in the log. The thicker arc, the higher the frequency of that arc. Like frequency statistics, the time visualization performance statistics as shown in Figure 4 7 also revealed the labels on activities and arcs and via colors and line thickness (on a red scale) for activities and arcs.

4.2.3 Log’s Statistics

The information obtained from the top bar of process discovery include the number of cases in the log, the number of case variants of the log, variance ratio, the number of activity instances in the event log of the overall logs is shown in Table 4 3.

Table 4 3 Event Log Data Statistics

No	Description	Quantity
1	Total number of cases	1188 cases
2	Total number of variants	11 variants
3	Number of activities	14 activities
4	Number of Department involved	3 (operational, distribution, finance)
5	Number of Parties involved	2 (provider & driver)

4.2.4 Cases Variants Inspection

Case variants are each process flow detected in the data. Following to the log’s statistic in section 4.2.3, the variance ratio is shown in Figure 4 8. Automatically, Apromore shows a process map of all possible case variants. As shown in Figure 4 8, there are 12 case variations.

ID	Cases	Frequency
1	1119	94.19%
2	32	2.69%
3	22	1.85%
4	4	0.34%
5	3	0.25%
6	3	0.25%
7	1	0.08%
8	1	0.08%
9	1	0.08%
10	1	0.08%
11	1	0.08%

Figure 4 8 The Distribution of Case Variations

4.2.5 Log Filtering

In order to properly construct an analytic instrument for SLAs proposal, certain requirements must be met. Firstly, a continuous process analysis is required for this sort of work. Essentially, the methods described in this study are not suitable for processes that are changing dynamically over time. Furthermore, for a Process Model Discovery method to successfully reproduce the relevant process model, a process must be run on a regular basis.

Based on Figure 4 8, the 1188 cases have 11 variants. Variant 1 represents 94.19% (1119 cases out of 1188 cases) in which it means that the major process is standardized. More than 90% of the overall cases is run as standardized. Therefore, the data is appropriate for further analysis. Among 11 variants, only variant 1 that shows all completed activities has done.

Therefore, a filter was applied by selecting 1 variant that represent 94.19% of the overall data, making it feasible for further processing. As a practical rule, at least 80% of the data should be valid to represent the entire dataset effectively. This approach ensures that the analysis remains manageable and meaningful while capturing most of the process variations and activities involved (Montgomery, 2020).

In this stage, the case variant filter is carried out. The variant 1 is retained and the other variants are removed to analyze the process's most common behavior. This can be done by entering the from variant and to variant values or using the time slider at the bottom of the filter criteria window. The filtered process map is presented in Figure 4 9 and Figure 4 10.

Figure 4 9 Filtered Process Map View by Case Frequency

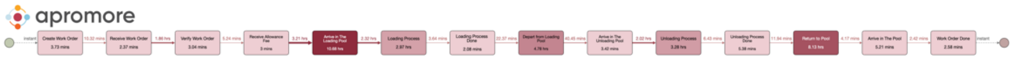

Figure 4 10 Filtered Process Map View by Average Case Duration

From the above evidence, the further analysis is to carried out through variant analysis.

4.3 Variant Analysis

Table 3 3 lists various products transported within X's LLC, including food, groceries, rice, chemicals, pharmaceutical drugs, electronics, batteries, pipes, iron, and tin. Grouping these products can help to formulate the effective SLAs. Below is a further analysis of these segmentation:

1. Food/Beverage
   - Products: Food, Groceries, Rice
   - Characteristics: These products are often perishable and require rapid handling and transport to maintain the freshness and quality. They may also need temperature-controlled environments. The foods often require temperature-controlled environments and faster delivery times to ensure freshness. While rice is less perishable than other food items, it still requires careful handling to avoid damage and contamination. These products requires a *Colt Diesel Double* (CDD) / *Colt Diesel Engkel* (CDE) fleet, depending on its product's quantity.
   - SLA Considerations: Given the perishable nature, SLAs for these products should be stringent, emphasis should be placed on rapid processing, minimal waiting times, and efficient transport routes.

2. Healthcare
   - Products: Chemicals, Pharmaceutical Drugs
   - Characteristics: These items are classified as hazardous and require special handling, including compliance with safety regulations and protocols, such as *Good Distribution Practices* (GDP) to ensure the patient safety, product integrity, and traceability. They may also need secure transport and specific storage conditions. These products often have stringent regulatory requirements for safe handling, storage, and transportation due to their hazardous nature, namely Personal Protection Equipments (PPEs).
   - SLA Considerations: SLAs for hazardous materials should account for additional handling and safety checks, which may extend processing times.

3. Electronics Supplies
   - Products: Electronic, Battery
   - Characteristics: Electronics and batteries are sensitive to handling and may require protection against damage during transit. Batteries, in particular, may have specific shipping regulations due to their hazardous nature. These products, mainly the lithium battery should follow the regulation from the Department of Transportation (DOT) to ensure the safe transportation of potentially hazardous materials and to prevent accidents during transit.

- SLA Considerations: SLAs should focus on safe and secure packaging, timely handling, and efficient transport to prevent damage.

4. Building Products
   - Products: Pipe, Iron, Tin
   - Characteristics: These are typically bulky, heavy items used in construction and manufacturing. They may require specialized equipment for handling (forklift) and transportation (using loss bak fleet).
   - SLA Considerations: SLAs for industrial materials should account for the complexity of loading and unloading processes, which can be time-consuming.

The followings are another considerations of classifying the product/commodity in formulating and formalizing SLAs (Ciriello, Snook, Hashemi, & Cotnam, 1999):

1. Handling Requirements
   Fragile Items: Commodities such as electronics and batteries require careful handling to prevent damage. This might involve special packaging (fragile sticker), careful loading/unloading, and handling instructions that can extend processing times.
   Perishable Goods: Food items, pharmaceuticals, and other perishable goods require temperature-controlled environments and expedited shipping to prevent spoilage, affecting both storage and transportation processes (Ammann, 2011).

2. Identifying Process Variability
   Lead Times: Different products might have varying lead times due to their handling and transportation needs.
   Processing Times: The time required to pick, pack, and ship products can vary significantly.
   Storage Requirements: Some products require special storage conditions (e.g., refrigeration for food, secure storage for chemicals).

3. Risk Management Related to Storage Conditions
   Temperature-Sensitive items and perishable goods need specific temperature conditions may have increased risk of being spoiled if not delivered on-time. Warehouses and vehicles must be equipped with refrigeration units, which may limit available resources and increase operational costs.
   The hazardous materials like batteries and electronics require special storage conditions and adherence to safety regulations, affecting both storage facilities and transportation options.

4. Customer-Specific Requirements
   Different customers may have unique requirements based on the products they deal with. Variant analysis allows the logistics company to customize SLAs based on individual customer needs. Customers requirements may include the customized SLAs and service level tiers (standard vs premium).

In relation to this grouping, in Apromore, this is achieved by means of log filters. Once the logs of the process variants have been extracted, Apromore allows to compare two or more variants of a business process. To retain the cases that include a specific attribute, in this case is the product/commodity attribute, the case attribute filter is used. For example, we will retain only cases that have the case attribute product of food, groceries, and rice to show the process map for Food/Beverage segment and successively.

In this stage, double filtering are applied. Firstly, only variant 1 which is retained. Secondly, case attribute filtering by segments. The process map of each segment is provided in **Appendix 2**. Using this data, the case duration is then calculated.

In Apromore, the average case duration can be analyzed using the performance mining capabilities of the tool. These logs can then be visualized as process maps, with annotated performance metrics of average case duration. To specifically view the average case duration, the tool display is switched into the overlay to show average duration for each activity in the process. Additionally, Apromore's Performance Dashboard provides a more detailed analysis, offering various performance metrics, including case duration, processing time, waiting time, and cycle time, through customizable charts and tables. Then, cases attribute filter are carried out. As a result of these case attribute filter, the summary of average case duration of each segments are calculated and summarized in Table 4 4.

Table 4 4 Summary of The Average Case Duration for Each Segments

Segment	Average Case Duration (mins)	Activity														Total (m)	Total (h)	Total (d)
		Create WO	Receive WO	Verify WO	Receive Allowance Fee	Arrive in Loading Pool	Loading Process	Loading Process Done	Depart from Loading Pool	Arrive in Unloading Pool	Unloading Process	Unloading Process Done	Return to Pool	Arrive in the Pool	WO Done			
Food / Beverage	Processing	2.60	5.19	6.84	2.80	298.20	133.80	2.54	348.60	94.20	126.60	107.40	352.20	8.42	1.77	2130.40	35.51	1.47
	Waiting	4.08	121.20	17.34	121.80	142.20	3.75	83.40	2.41	109.20	2.45	25.72	0.99	4.70	0.00			
Healthcare	Processing	3.90	2.15	2.89	3.00	676.80	180.00	1.99	276.60	1.24	199.80	3.78	489.60	1.14	2.65	2467.45	41.12	1.71
	Waiting	11.14	117.60	1.99	183.60	142.80	3.62	21.46	3.11	117.60	6.67	8.56	3.26	0.50	0.00			
Electrical Supplies	Processing	1.39	3.81	3.88	3.36	87.60	123.60	2.78	150.00	1.76	135.00	9.34	429.00	3.00	1.75	2198.46	36.64	1.53
	Waiting	1.16	47.53	48.40	276.00	90.60	3.25	2.48	555.00	145.20	4.79	49.69	2.09	16.00	0.00			
Building Products	Processing	3.34	7.70	5.24	2.42	829.80	310.20	4.57	1363.80	66.60	304.80	2.81	687.60	256.20	1.88	5510.33	91.84	3.83
	Waiting	0.94	1.39	28.25	474.60	115.20	6.19	102.00	384.00	258.00	96.60	61.80	69.60	64.80	0.00			

Time perspective analysis in the process discovery consists of two components, namely processing time and waiting time. Processing time is the time span from the start to the completion of a specific activity within a process. It is the period when work is actually being performed on a case, as opposed to waiting time, which is when the case is idle. Processing time helps to evaluate the efficiency and performance of individual activities. Shorter processing times usually indicate higher efficiency, whereas longer times might suggest inefficiencies or complexities (kumar & Sudarsanan, 2020).

Waiting, in general terms, refers to the duration that a particular case or activity spends in a state of inactivity between two events in a process. Essentially, it is the period during which no active processing is happening, and the case is idle. Waiting time is a critical metric in time perspective analysis as it helps identify inefficiencies and bottlenecks within a process. Waiting time is used to assess the efficiency of a process (Smet, 2014). High waiting times can indicate bottlenecks or delays that may be caused by resource constraints, procedural inefficiencies, or other factors.

1. Process Bottlenecks: By analyzing waiting times, one can identify steps in the process where cases spend an excessive amount of time waiting, signaling potential bottlenecks.
2. Resource Utilization: Understanding waiting times helps in analyzing how well resources are utilized. Long waiting times might suggest underutilization or misallocation of resources.
3. Cycle Time Reduction: Reducing waiting times is a common strategy for decreasing overall cycle time and improving process performance.

This indicates that a SLA violation is directly influenced by a service provider's late delivery. Processing time is very important when it comes to processes that are governed by SLA. Process delays frequently result in SLA violations. From the provider's point of view, it is essential to continuously assess and analyze its service delivery operations to prevent violations. All of these methods, meanwhile, are limited to monitoring and cannot be used to identify problems with the processes themselves.

To formulate SLAs, it's essential to highlight and analyze the time taken for each critical activity in the work order fulfillment process. From the provided process flow, the activities that should be highlighted for further time analysis are:

1. Create Work Order to Receive Work Order

   This includes the time taken from creating a work order to its receipt. Analyzing this duration helps measure the responsiveness of the system or personnel involved in initial stages.

2. Receive Work Order to Verify Work Order

   Time taken to verify the received work order. This is crucial for ensuring the accuracy and completeness of the order before proceeding.

3. Receive Allowance to Depart to The Loading Pool

   Time taken from receiving the allowance to departing to the loading pool. It checks the preparation and mobilization efficiency.

4. Arrive in The Loading Pool to Loading Process

	The duration from arriving at the loading pool to starting the loading process. It measures potential waiting times and handling readiness.
5.	Loading Process Duration
	The total time taken to complete the loading process. It assesses operational efficiency and handling speed.
6.	Depart from The Loading Pool to Arrive in The Unloading Pool
	Transit time between the loading pool and unloading pool. This evaluates transportation efficiency.
7.	Arrive in The Unloading Pool to Unloading Process
	Time taken from arriving at the unloading pool to starting the unloading process. It measures potential waiting times and unloading readiness.
8.	Unloading Process Duration
	The total time taken to complete the unloading process. It assesses the efficiency and speed of the unloading operation.
9.	Unloading Process Done to Return to The Pool
	Time taken after the unloading process to return to the pool. This includes any necessary administrative tasks or final steps before returning.

4.3.1 The Processing Time to Create, Receive, and Verify WO

The process time to create WO ranges from 1.39 mins (Electrical Supplies) to 3.90 mins (Healthcare). The process time to receive WO ranges from 2.15 mins (Healthcare) to 7.70 mins (Building Products). While the process time to verify WO ranges from 2.89 mins (Healthcare) to 6.84 mins (Food / Beverage). The processing times across segments are relatively low, indicating good responsiveness in initiating and completing work orders. Overall, the company exhibits good responsiveness and efficiency in segments with shorter processing and waiting times.

4.3.2 The Loading-Unloading Processing Times

The following analysis will highlight the processing time of loading-unloading activity. The diversity of products needs customized handling procedures, which directly impacts loading and unloading times. Furthermore, grouping products based on their handling requirements allows for more accurate and realistic SLA formulation.

Table 4 4 is generated by calculating the total of the average case duration on each activity within every case, including the average processing time and waiting time. Average case duration refers to the average time takes to complete a particular case (or instance) of a process from start (create WO) to finish (complete WO).

In the food and beverage distribution segment, the loading process takes an average of 133.80 minutes, while the unloading process takes 126.60 minutes. The relatively moderate processing times for loading and unloading can be attributed to the perishable nature of food and beverage products, necessitating efficient handling to maintain product quality. These lead times are relatively shorter because these products often require rapid turnover to maintain freshness and quality. However, the loading and unloading times can still be considerable due to the need for careful handling and adherence to safety regulations. The total average case duration for the food and beverage segment is 1.48 days, indicating that a 2-day SLA is likely achievable for this segment.

For the healthcare segment, the loading process is significantly longer, averaging 180 minutes, while the unloading process takes 199.80 minutes. The extended processing times are likely due to the stringent handling and regulatory requirements associated with healthcare products, such as pharmaceuticals and chemicals. These items often require careful verification and compliance with safety protocols, contributing to longer durations. The loading and unloading times for healthcare segment are typically longer (compared to the Food/Beverage segment) due to the need for meticulous documentation, ensuring that all items are accounted for and are handled according to regulatory standards. The sensitive nature of these products means that loading and unloading must be done with great care to prevent damage and contamination, often requiring specialized PPEs. The total average case duration for healthcare is 1.71 days, suggesting that a 2-day SLA could also be feasible, though the higher processing times should be monitored closely.

In the electrical supplies segment, the loading process averages 123.60 minutes, and the unloading process takes 135 minutes. These times are comparatively efficient, reflecting the nature of electrical supplies, which typically have standardized packaging and handling procedures. Despite the efficiency in loading and unloading, the total average case duration for this segment is 1.53 days. The loading and unloading times for these products are influenced by factors such as fragility, size, and the necessity for precise handling. Electrical Supplies have a shorter loading and unloading processing time (123.60 mins and 135 mins) compared to healthcare (180 mins and 199.80 mins). This indicates that Electrical supplies might involve less complex handling and safety procedures compared to healthcare products, leading to faster processing times. Electrical supplies also come in standard packaging sizes that are easier to load/unload, whereas healthcare products might require more careful handling due to their nature. Moreover, ensuring that all components are correctly inventoried and checked for quality can add to the time required, particularly if the shipments are large and contain many different items. This indicates that while the segment is close to the 2-day threshold, ensuring consistent performance will require attention to any potential bottlenecks in other parts of the process.

The building products segment exhibits the most extensive processing times, with the loading process averaging 310.20 minutes and the unloading process at 304.80 minutes. These extended durations are likely due to the bulk and weight of building products, which require more time for handling and transportation. The total average case duration for building products is 3.83 days. The loading and unloading times for building products can be particularly extensive due to the heavy and cumbersome nature of these materials. Specialized equipment such as cranes, forklifts, and heavy-duty trucks are often required to handle these items safely and efficiently. Additionally, the logistics of moving large quantities of building materials to construction sites can be complex, necessitating detailed coordination and planning to ensure timely delivery and to avoid delays in construction projects. Given this, proposing a 2-day SLA for building products would not be realistic without significant improvements in handling and logistics processes.

In summary, the lead time for different products is closely linked to the specific loading and unloading requirements inherent to each product category. Food and beverage products, healthcare items, electrical supplies, and building materials all present unique challenges that influence their respective lead times.

4.3.3 The Transportation Processing Time

The transportation process in logistics is significantly influenced by the distance between the loading and unloading pools. Longer distances naturally result in extended travel times, impacting the overall duration of the logistics process. For instance, if the pools are located far apart, transport vehicles spend more time in transit, which can delay subsequent steps such as unloading and returning to the pool. This effect is particularly pronounced in segments where the transport of goods requires adherence to strict timelines, such as in the distribution of perishable food and beverage products.

4.3.4 The Waiting Time to Loading-Unloading Process

The waiting time for loading and unloading in logistics operations is heavily influenced by the conditions and density of the warehouse. Congested warehouses with limited space for maneuvering and storage can significantly increase waiting times as vehicles may need to queue before they can be serviced. High-density conditions, particularly during peak operational hours, exacerbate these delays, leading to longer processing times. Additionally, the efficiency of warehouse operations, including the availability of equipment like forklifts and trained personnel, plays a crucial role in determining how quickly loading and unloading can be completed.

Poorly organized warehouses or those operating at or beyond capacity can create bottlenecks, further extending waiting times. Implementing strategies such as optimizing warehouse layouts, scheduling staggered loading/unloading times, and employing real-time tracking systems can help alleviate these issues. By improving warehouse efficiency, logistics companies can reduce waiting times, ensuring a smoother and more predictable logistics process that aligns with established SLAs.

4.3.5 Case Duration Distribution

To propose an effective SLAs for the logistics sector, it is essential to base the SLA on robust data analysis derived from average case duration, case distribution, and percentage metrics. The average case duration provides a baseline measure of the typical time required to complete a work order from initiation to fulfillment. This metric helps identify realistic time frames that can be promised to customers. Case distribution analysis, which examines the variability and frequency of different case durations, highlights the range and spread of completion times, revealing insights into operational consistency and identifying outliers. This allows for setting more precise SLAs that account for most cases while recognizing exceptional scenarios. Finally, analyzing the percentage of cases that meet or exceed specific time thresholds enables the formulation of SLAs that reflect achievable service standards based on historical performance data.

A key rule in this approach is that the SLA should cover at least 80% of cases within a specific time frame. This ensures that the SLA is both ambitious and attainable, covering most work orders while allowing for some flexibility in exceptional circumstances (Montgomery, 2020). By integrating these three elements and adopting the 80% rule, the proposed SLAs can be tailored to ensure they are realistic and achievable, fostering improved performance and higher customer satisfaction. This approach ensures that the SLAs are grounded in empirical evidence, promoting transparency, accountability, and continuous improvement within the logistics operations.

4.3.5.1 Food/Beverage Segment

The total processing time is 2130.40 minutes, equivalent to approximately 35.51 hours or 1.47 days. This duration represents the time fulfilment to create WO until complete WO for handling food/beverage products (food, groceries, and rice). In addition to the above calculation, the temporal statistical data has also obtained. Temporal statistical data of food/beverage segment is shown in Table 4 5.

Table 4 5 Temporal Statistic Data of Food/Beverage Segment

No	Description (case duration)	Total
1	Average	1.47 Days
2	Median	1.35 Days
3	Minimum	1.23 Days
4	Maximum	1.94 Days

Table 4 5 shows the temporal statistic data of food/beverage segment. The average case duration is the mean time taken for cases to be completed. An average of 1.47 days, indicates that, on average, cases are completed within a day and a half. This metric helps in understanding the overall efficiency of the process. The median is the middle value of the dataset, meaning that 50% of the cases are completed in less than 1.35 days and the other 50% in more than 1.35 days. The median is a better measure of central tendency when the data is skewed, as it is less affected by outliers. A median of 1.35 days suggests that the typical case duration is slightly shorter than the average, indicating some longer-duration cases that may be skewing the average upwards. The maximum duration of 1.94 days indicates the longest time taken to complete a case. Therefore, in formulating the SLA the average case duration is considerable. Overall, while the process appears to be relatively efficient with most cases being resolved in under 2 days. Figure 4 11 shows the distribution graph of case duration for food/beverage segment.

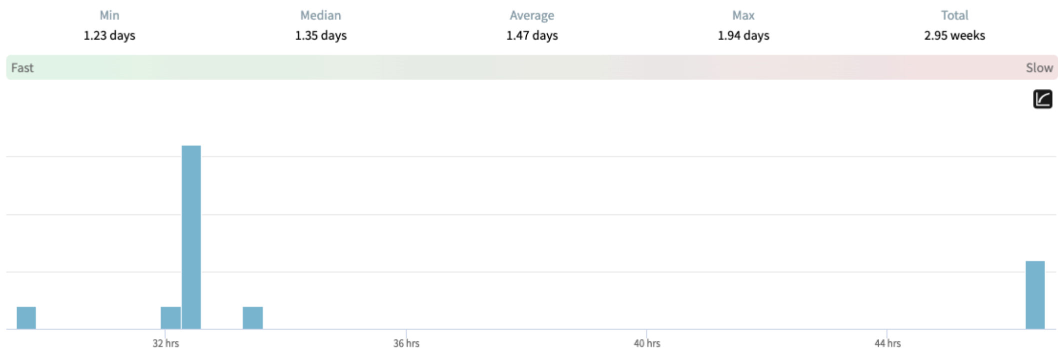

Figure 4 11 Case Duration Distribution Graph of Food/Beverage Segment

Figure 4 11 provides a visual representation of the case duration distribution, showing the frequency of cases completed within specific time frames. The x-axis represents the duration in days, while the y-axis represents the number of cases. All cases are completed within 1 to 2 days. There are peaks at around 1.35 days and 1.47 days, aligning with the median and average case durations, respectively. There are some outliers that extend the duration significantly up to 1.94 days. This is subjected to the transportation of less-perishable products in this segment, packed rice. However, in this segment, all cases are completed in a less than 2 days. The efficiency of case handling is generally high, with a median and average duration close to each other, demonstrating consistency.

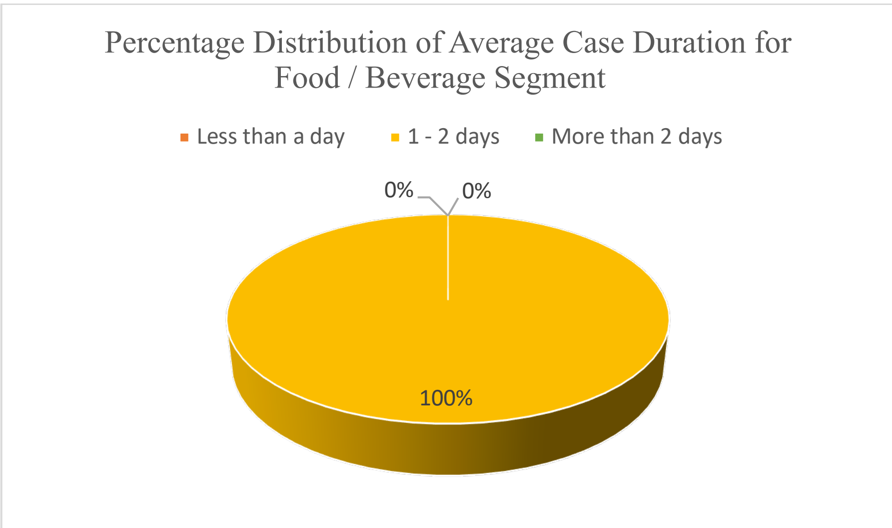

Figure 4 12 The Percentage Distribution of Food/Beverage Segment

Refer to Figure 4 12, the whole cases has completed within 2 days. This is likely crucial for perishable goods that require rapid handling to maintain quality and freshness. It demonstrates a strong capability in fulfilling work orders with most orders completed within 1.5 days.

4.3.5.2 Healthcare Segment

The total processing time is 2467.45 minutes, equivalent to approximately 41.12 hours or 1.71 days. This duration represents the time needed to create WO until complete WO for handling healthcare products (chemicals and pharmaceutical drugs). In addition to the above calculation, the temporal statistical data has also obtained. Temporal statistical data of healthcare segment is shown in Table 4 6.

Table 4 6 Temporal Statistic Data of Healthcare Segment

No	Description (case duration)	Total
1	Average	1.71 days
2	Median	1.68 days
3	Minimum	1.16 days
4	Maximum	6.92 days

Table 4 6 shows the temporal statistic data of healthcare segment. This segment shows a process with a wider range of case durations compared to the food/beverage segment. The average case duration of 1.71 days suggests that, on average, cases are resolved within approximately one and a half days. The median duration of 1.68 days indicates that half of the cases are completed in less than this time, and the other half take longer. Since the median is slightly lower than the average, this suggests a relatively balanced distribution of case durations, with only a very few faster durations slightly affecting the average. The proximity of the average (1.71 days) and median (1.68 days) durations indicates a relatively symmetrical distribution of case durations. Minimum Case Duration (1.16 Days) shows the fastest time a case has been completed, while the maximum case duration (6.92 Days) shows the longest time taken for a case, showing potential bottlenecks or delays in the process. While most cases are processed within a consistent timeframe, the significant outliers indicate potential bottlenecks and areas for improvement. Figure 4 13 shows the distribution graph of case duration for healthcare segment.

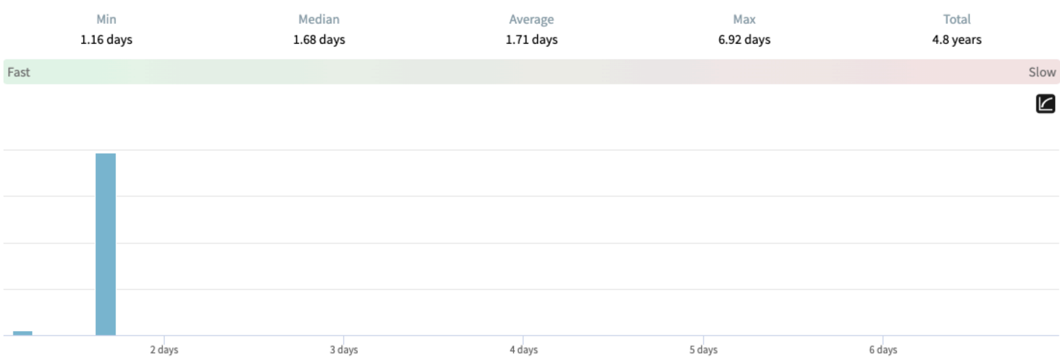

Figure 4 13 Case Duration Distribution Graph of Healthcare Segment

Figure 4 13 shows a significant peak around the 2 days, indicating that most cases are clustered within this duration range. The majority of cases are completed within a range of around 1.5 to 2 days, which aligns with the median (1.68 days) and average (1.71 days) case durations. This indicates consistency in the process duration for the majority of cases. The efficiency of case handling is high, with both the median and average durations being close to each other, which suggests consistent performance. The small difference between the median and mean durations indicates a relatively low level of skewness in the data. The distribution shows a sharp drop-off after 2 days. There are notable outliers where the case duration extends significantly reaching up to 6.92 days. This suggests the presence of late deliveries. A closer look to the percentage distribution is conceived in Figure 4 14.

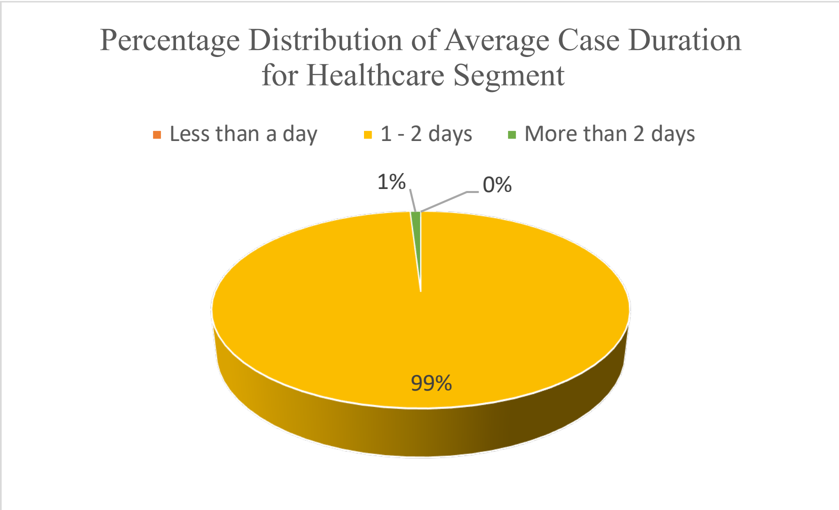

Figure 4 14 The Percentage Distribution of Healthcare Segment

Given in Figure 4 14 that 99% of cases are completed within 2 days, which aligns with the average and median case duration. A very small portion of cases extends beyond 2 days, covering 1% of the total cases. This chart reflects a high level of efficiency and minimal variability within the primary range. It express the performance stability. However, the presence of the 1% outliers can be highlighted for further improvement.

4.3.5.3 Electrical Supplies Segment

The total processing time is 2646.77 minutes, equivalent to approximately 44.11 hours or 1.84 days. This duration represents the time needed to create WO until complete WO for handling healthcare products (electronics and battery). In addition to the above calculation, the temporal statistical data has also obtained. Temporal statistical data of electrical supplies segment is shown in Table 4 7.

Table 4 7 Temporal Statistic Data of Electrical Supplies Segment

No	Description (case duration)	Total
1	Average	1.53 Days
2	Median	1.37 Days
3	Minimum	1.03 Days
4	Maximum	4.69 Days

Based on Table 4 7, the average case duration (1.53 Days) indicates the mean time taken for the completion of the cases, influenced by all durations including outliers. Median case duration (1.37 Days) indicates that half of the cases are completed in less than this time, and the other half take longer. Minimum case duration (1.03 Days) shows the fastest time a case has been completed, while the maximum case duration (4.69 Days): This shows the longest time taken for a case. The median case duration of 1.37 days indicates that half of the cases are completed in less than this time, and the other half take longer. The maximum case duration of 4.68 days highlights the longest time taken for any case to be completed. This is significantly higher than both the average and median durations, indicating that some cases experience substantial delays. Figure 4 15 shows the distribution graph of case duration for electrical supplies segment.

Figure 4 15 Case Duration Distribution Graph of Electrical Supplies Segment

The graph provides a visual representation of the case duration distribution, The majority of cases are completed within a range of 1 to 2 days, aligning with the median and average case durations. There is a significant peak around the 1.37 to 1.53-day mark, indicating that most cases are clustered within this duration range. There are notable outliers where the case duration extends significantly beyond the typical 1 to 2 days, with some cases reaching up to 4.69 days. This suggests the presence of delays in certain instances. The efficiency of case handling is high, indicating consistency and efficiency. Figure 4 16 offers a more detail look at the percentage distribution.

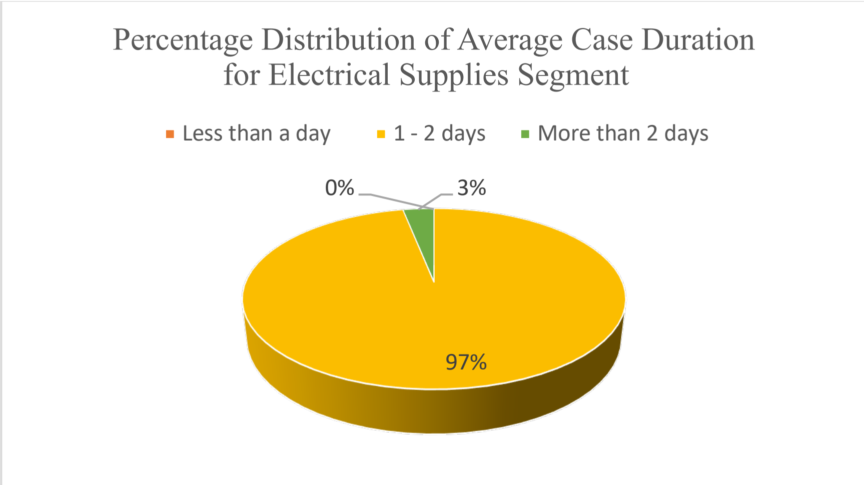

Figure 4 16 The Percentage Distribution of Electrical Supplies Segment

Following Figure 4 16, 97% of cases are completed within 2 days, which aligns with the average and median case duration. A very small portion of cases extends beyond 2 days, covering 3% of the total cases. The 97% cases completed within 2 days reflects a high level of efficiency and minimal variability within the primary range. It express the performance stability. However, the presence of the 1% outliers, pinpointing the area for potential improvement to optimize the performance delivery.

4.3.5.4 Building Products Segment

The total processing time is 5510.33 minutes, equivalent to approximately 91.84 hours or 3.83 days. This duration represents the time needed to create WO until complete WO for handling building products (iron, tin, pipe). In addition to the above calculation, the temporal statistical data has also obtained. Temporal statistical data of building products segment is shown in Table 4 8.

Table 4 8 Temporal Statistic Data of Building Products Segment

No	Description (case duration)	Total
1	Average	3.76 Days
2	Median	3.43 Days
3	Minimum	3.21 Days
4	Maximum	4.57 Days

As established in Table 4 8, both the average (3.76 days) and median (3.43 days) durations are relatively high compared to other segments, indicating that the process cycle for building products is longer and may involve complex steps. Since the median is slightly lower than the average, it suggests a right-skewed distribution, where some longer-duration cases are increasing the average. The maximum case duration of 4.57 days highlights the longest time taken for any case to be completed. This is not drastically higher than the average and median, indicating that while there are some longer-duration cases, they are not extreme outliers. The closely of the average (3.76 days) and median (3.43 days) case durations suggests that the data is somewhat normally distributed, but with a slight skew towards longer durations. Figure 4 17 shows the distribution graph of case duration for building products segment.

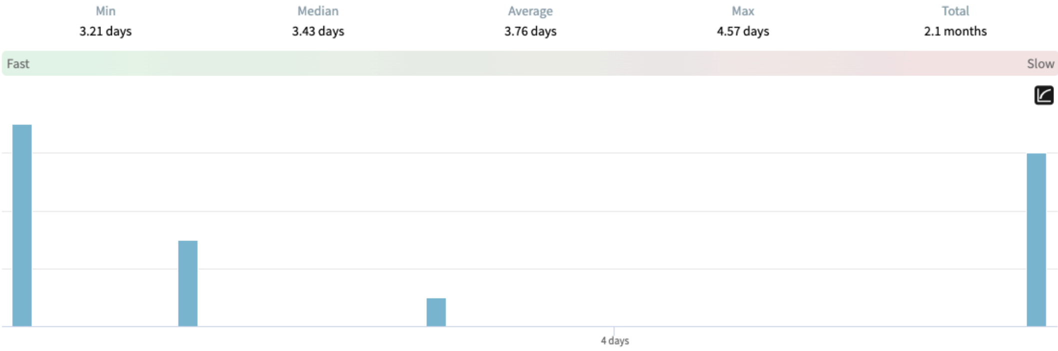

Figure 4 17 Case Duration Distribution Graph of Building Products Segment

Figure 4 17 reveals the distribution variety of case durations with multiple peaks. The case duration distribution graph shows two distinct peaks: First peak is around 3.21 days, and the second peak is around 4.57 days. This suggests the presence of two subgroups within the building products segment: **1)** Cases with durations below 4 days and **2)** Cases with durations longer than 4 days. A detailed analysis reveals that the second peak (around 4.57 days) corresponds to one specific product out of the three products within this segment.

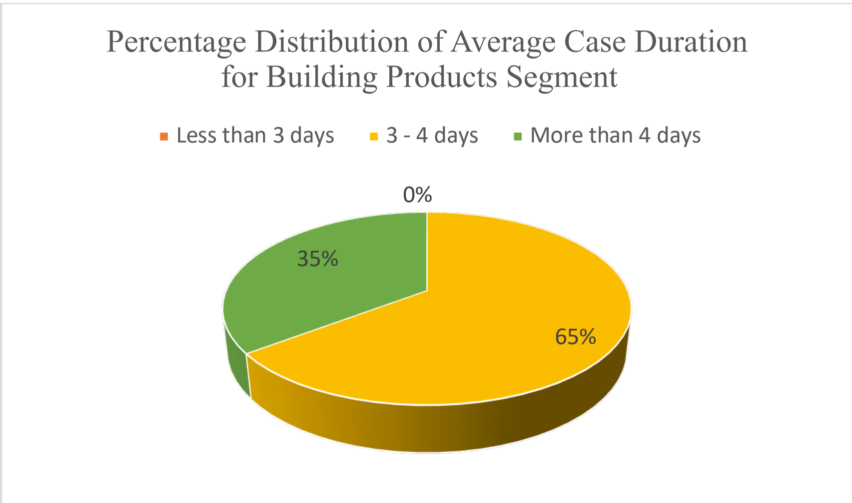

Figure 4 18 The Percentage Distribution of Building Products Segment

To analyze and group the data as shown in the Figure 4 18, the building products segment has no cases with durations less than 3 days, highlighting that this segment's cases generally take longer to fulfill. It devided into two categories, we can define the groups based on the duration of the cases. 65% of the cases in the building products segment fall within the 3 - 4 days range, while the rest took longer than 4 days. The longer case durations could be attributed to specific products requiring more time for logistics and handling, because this sub segment is distributed the pipe into the another pool which is farther.

4.4 Result and Evaluation

4.4.1 SLAs Proposal

The purpose of this SLAs proposal is to outline the expected service levels for handling different product segments based on the average case duration data obtained from process mining analysis. The goal is to set realistic and achievable targets that ensure efficient and timely handling of cases across the healthcare, electrical supplies, and building products segments.

4.4.1.1 Case Duration Overview

Based on the data obtained from PM analysis, the summary of the temporal statistic of each segment is provided in Table 4 9.

Table 4 9 Summary of The Temporal Statistic of Each Segments

No	Segment	Case Duration			
		Minimum	Median	Average	Maximum
1	Food / Beverage	1.23	1.35	1.47	1.94
2	Healthcare	1.36	1.48	1.71	6.92
3	Electrical Supplies	1.03	1.37	1.53	4.69
4	Building Products	3.21	3.43	3.76	4.57

4.4.1.2 Proposed SLA by Segments

Based on the data provided for different segments and activities in the logistics process, here is a proposed SLA for each segment.

1. Food / Beverage Segment
   Proposed SLA: 2 days
   Justification: Given the narrow range of case durations and the high percentage (100%) of cases resolved within the average duration of 1.47 days, setting an SLA of 2 days is both realistic and achievable. This SLA ensures prompt handling while accommodating slight variations in case duration.

2. Healthcare Segment
   Proposed SLA: 2 days
   Justification: The healthcare segment shows a wider range of case durations, with a significant maximum duration of 6.92 days. While 99% of cases are within the average duration, a standard SLA of 2 days is reasonable to cover typical cases.

3. Electrical Supplies Segment
   Proposed SLA: 2 days
   Justification: Similar to healthcare, the electrical supplies segment has a broad range of case durations. With 97% of cases within the average duration, an SLA of 2 days is suitable.

4. Building Products Segment
   Proposed SLA: a) 4 days, b) 5 days

Justification: The building products segment has distinct subgroups, with 65% of cases resolved within the average duration and 35% taking up to the maximum duration. The proposed SLA of 4 days addresses the typical handling time, while the second SLA proposal accounts for the second peak in the distribution, primarily related to one specific product.

4.4.2 KPI Recommendation

Time perspective analysis in PM can significantly enhance the measurement and management of KPIs in X's LLC, such as "*on-time delivery rates*" and "*order cycle time*." Apromore's capabilities allow logistics companies to analyze their processes from a temporal viewpoint, providing valuable insights into the timing and duration of various activities within the supply chain. By leveraging this analysis, X'S LLC can identify bottlenecks, inefficiencies, and deviations from the planned schedule, which are crucial for improving their performance.

One of the primary KPIs in logistics is the "*on-time delivery rate*," which measures the percentage of orders delivered to customers within the promised timeframe. Using Apromore, companies can conduct a detailed analysis of their delivery processes, tracking the time taken for each step from order receipt to final delivery. This time perspective analysis helps in pinpointing delays and understanding their root causes, whether they stem from internal processing issues, supplier delays, or transportation problems. By addressing these issues, companies can improve their on-time delivery rates, ensuring higher customer satisfaction and better service reliability.

Another critical KPI is the "order cycle time," which refers to the total time taken from receiving an order to fulfilling it. Apromore's process mining tools enable logistics company to map out the entire order fulfillment process, highlighting the time taken at each stage. This comprehensive time analysis allows companies to identify stages where time is being wasted and opportunities for process optimization. For instance, if the analysis reveals that a significant amount of time is spent in warehouse picking and packing, companies can invest in automation or better training for staff to reduce this duration. By continuously monitoring and analyzing the order cycle time through Apromore, logistics company can achieve faster order fulfillment, thereby improving overall efficiency and customer satisfaction.

Creating the KPIs for this research involves focusing on metrics that can be directly influenced by PM insights and that align with the goals of enhancing service levels in logistics. Here are some recommended KPIs:

1. On-Time Delivery Rates:

   The on-time delivery rate measures the percentage of deliveries made within the agreed SLA timeframe. From the data provided, we can calculate the on-time delivery rate by comparing the number of deliveries that meet the SLA requirements to the total number of deliveries. By analyzing the average case durations for each segment, the SLAs are determined.

   - Formula:

     $$\text{On Time Delivery Rate} = \left(\frac{\text{Number of on-time deliveries}}{\text{Total number of deliveries}}\right) \times 100\%$$

- Target: ≥ 95% (based on the percentage of case duration distribution)
- Improvement Strategies: X’s LLC can focus on segments with higher variability and outliers. This can be done by bottlenecks analysis to improve on-time delivery rates and minimize the late deliveries.

2. Order Cycle Time:

    Order cycle time is the total time required to create the WO until complete the WO. The total processing and waiting times for each segment provide insights into the overall order cycle time. By summing these durations, companies can determine how long it takes to complete an order from start to finish.

    - Formula:

    $$\text{Order Cycle Time} = \text{Total Processing Time} + \text{Total Waiting Time}$$

    $$\text{Order Cycle Time} = \frac{\sum(\text{Completion Time} - \text{Creation Time})}{\text{Total Number of Orders}}$$

    - Target: by segment, the average case duration
    - Improvement Strategies: To reduce order cycle times, X’S LLC can streamline processes and eliminate bottlenecks.

CHAPTER 5
CONCLUSION

5.1 Conclusion

This research is objected to propose the formalized SLAs using PM analysis through the time perspective of the processes. The formalized SLAs would be valuable for the company to develop relevant and measurable KPIs such as "*On-Time Delivery Rates*" and "*Order Cycle Time*." This movement helps to increase service delivery and customer satisfaction.

Through the implementation of PM^2, this research includes five main stages which are Planning, Extraction, Processing, PM Analysis, and Evaluation. The variant analysis is carried out in consideration that X's LLC serves multiple customers with high variety of products. The SLA is then proposed for each variants and KPIs recommendation is generated based on the data-driven approach. The following are the conclusions obtained from the analysis:

1. The process discovery results found 1,188 cases, 11 case variations, 14 activities, and 3 resources in the work order fulfillment business process in the time period January 2023 – December 2023.
2. The result of time perspective analysis resulted the total average case duration of:
   a. Food and Beverage: 1.47 days
   b. Healthcare: 1.71 days
   c. Electrical Supplies: 1.53 days
   d. Building Products: 3.83 days
3. Therefore, the proposed SLAs are:
   a. Food and Beverage: 2 days
   b. Healthcare: 2 days
   c. Electrical Supplies: 2 days
   d. Building Products: 4 days (category I) and 5 days (category II)
4. KPIs recommendation:
   a. Food and Beverage:
      - On-time delivery rate: 95%
      - Order Cycle Time: 1.47 days
   b. Healthcare:
      - On-time delivery rate: 95%
      - Order Cycle Time: 1.71 days
   c. Electrical Supplies:
      - On-time delivery rate: 95%
      - Order Cycle Time: 1.53 days
   d. Building Products:
      - On-time delivery rate: 95%
      - Order Cycle Time: 3.83 days

5.2 Future Works

This research opens up several avenues for future research. One potential area for future work is to extend the PM techniques to other service industries beyond the logistics sector (Zhang & Chi, 2022). Further research could also explore the application of PM in a multi-stakeholder environment, where the SLAs need to be negotiated and agreed upon by various parties involved, such as the logistics provider, the customer, and any third-party service providers (Sanchez-Escobar et al., 2021). The future research could also explore on several key areas:

1. Broadening the Dataset
   Cross-Company Comparisons: Collect and analyze data from multiple logistics companies to compare SLAs performance and identify industry-wide best practices. Expanding the scope of the research to include a wider range of logistics processes and additional case studies from different companies would provide a more comprehensive understanding of the applicability and benefits of formalized SLAs using PM. This comparative analysis could highlight industry-specific challenges and best practices.

2. Advanced PM Techniques
   Root Cause Analysis: Apply advanced PM techniques to understand the root causes of SLA violations and develop targeted interventions. Consequently, logistics companies can implement more precise corrective actions, such as optimizing resource allocation, refining process workflows, or introducing new technologies to mitigate these issues. Ultimately, this approach not only improves SLA compliance but also enhances overall operational efficiency and customer satisfaction.

3. Performance Metrics and Evaluation
   Refined Metrics: Continuously refine the performance metrics used to evaluate SLA compliance and process efficiency. Additionally, incorporating predictive and prescriptive analytics can help forecast future performance trends and recommend proactive adjustments. By establishing a robust framework for continuous performance evaluation, logistics companies can ensure their SLAs remain relevant and their operations remain efficient, ultimately leading to enhanced customer satisfaction and competitive advantage.

5.3 Implication

It is crucial to emphasize the dynamic nature of SLAs of a logistics company. The recommendations derived from PM analysis must be viewed not as static directives but as evolving guidelines that require regular updates and monitoring. The logistics industry is characterized by constant changes in operational parameters, customer demands, market conditions, and technological advancements. Consequently, the SLAs, which govern the service quality and performance standards, must be agile enough to adapt to these fluctuations.

One of the significant implications of this research is the necessity for a systematic approach to incorporating additional data into the existing SLA framework. As new data becomes available, whether through advanced tracking systems, customer feedback, or changes in regulatory requirements, it should be meticulously analyzed and integrated into the SLAs. This integration ensures that the SLAs remain relevant and reflective of the current operational realities. By continuously updating SLAs, the logistics company can maintain high service quality, meet evolving customer expectations, and stay competitive in a rapidly changing market.

Furthermore, the inclusion of additional data in the SLA monitoring process enhances the accuracy and precision of the performance metrics. PM techniques allow for the extraction of actionable insights from vast datasets, identifying patterns and anomalies that might not be apparent through traditional analysis methods. By leveraging these insights, the logistics company can pinpoint specific areas for improvement, optimize resource allocation, and streamline processes. This data-driven approach not only bolsters the company's operational efficiency but also fosters a culture of continuous improvement and innovation.

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Appendix 1 Cases Variants

Variant	Details	Number of Cases	Percentage	Remark
1	1 Create Work Order 2 Receive Work Order 3 Verify Work Order 4 Receive Allowance Fee 5 Arrive in The Loading Pool 6 Loading Process 7 Loading Process Done 8 Depart from Loading Pool 9 Arrive in The Unloading Pool 10 Unloading Process 11 Unloading Process Done 12 Return to Pool 13 Arrive in The Pool 14 Work Order Done	1119	94.19%	COMPLETED ORDERS
2	1 Verify Work Order 2 Receive Allowance Fee 3 Arrive in The Loading Pool 4 Loading Process 5 Loading Process Done 6 Depart from Loading Pool 7 Arrive in The Unloading Pool 8 Unloading Process 9 Unloading Process Done 10 Return to Pool 11 Arrive in The Pool 12 Work Order Done	32	2.69%	INCOMPLETE ORDERS

3	Create Work Order 2 Receive Work Order	22	1.85%	INCOMPLETE ORDERS
4	1 Create Work Order 2 Receive Work Order 3 Verify Work Order 4 Receive Allowance Fee 5 Arrive in The Loading Pool	4	0.34%	INCOMPLETE ORDERS
5	1 Create Work Order 2 Receive Work Order 3 Verify Work Order 4 Receive Allowance Fee	3	0.25%	INCOMPLETE ORDERS
6	1 Create Work Order	3	0.25%	INCOMPLETE ORDERS
7	1 Create Work Order 2 Receive Work Order 3 Verify Work Order 4 Receive Allowance Fee 5 Arrive in The Loading Pool 6 Arrive in The Loading Pool 7 Loading Process 8 Loading Process 9 Loading Process Done 10 Loading Process Done 11 Depart from Loading Pool 12 Depart from Loading Pool 13 Arrive in The Unloading Pool 14 Arrive in The Unloading Pool 15 Unloading Process 16 Unloading Process	1	0.08%	INCOMPLETE ORDERS

	17 Unloading Process Done 18 Unloading Process Done 19 Return to Pool 20 Return to Pool 21 Arrive in The Pool 22 Arrive in The Pool 23 Work Order Done 24 Work Order Done			
8	1 Create Work Order 2 Receive Work Order 3 Verify Work Order 4 Receive Allowance Fee 5 Arrive in The Loading Pool 6 Loading Process 7 Loading Process Done 8 Depart from Loading Pool 9 Loading Process 10 Arrive in The Unloading Pool 11 Unloading Process 12 Unloading Process Done 13 Return to Pool 14 Arrive in The Pool 15 Work Order Done 16 Work Order Done	1	0.08%	INCOMPLETE ORDERS
9	1 Receive Work Order 2 Create Work Order 3 Verify Work Order 4 Receive Allowance Fee 5 Arrive in The Loading Pool 6 Loading Process 7 Loading Process Done	1	0.08%	INCOMPLETE ORDERS

	8 Depart from Loading Pool 9 Arrive in The Unloading Pool 10 Unloading Process 11 Unloading Process Done 12 Return to Pool 13 Arrive in The Pool 14 Work Order Done			
10	1 Receive Work Order 2 Verify Work Order 3 Receive Allowance Fee	1	0.08%	INCOMPLETE ORDERS
11	1 Create Work Order 2 Create Work Order	1	0.08%	INCOMPLETE ORDERS

Appendix 2 Process Map of Each Variants View by Average Case Duration

1. Food / Beverage

2. Healthcare

3. Electrical Supplies

4. Building Products

Appendix 3 Sample of Event Log to Visualize How Fuzzy Miner Algorithm in Apromore Works

No_DA	Commodity	Status	updateAt	finishAt	updateBy
WO.1007.01.23.12650	OBAT	Work Order Dibuat	2023/01/12 13:55:08	2023/01/12 13:59:08	Admin DKI
WO.1007.01.23.12650	OBAT	Work Order Diterima	2023/01/12 14:08:31	2023/01/12 14:10:37	13389305000119
WO.1007.01.23.12650	OBAT	Verifikasi Work Order	2023/01/12 14:45:43	2023/01/12 14:48:41	Admin DKI
WO.1007.01.23.12650	OBAT	Uang Jalan Diterima	2023/01/12 14:50:37	2023/01/12 14:53:35	Admin DKI
WO.1007.01.23.12650	OBAT	Tiba Dilokasi Pemuatan	2023/01/12 17:57:56	2023/01/13 05:40:37	13389305000119
WO.1007.01.23.12650	OBAT	Proses Pemuatan	2023/01/13 08:05:47	2023/01/13 11:07:13	13389305000119
WO.1007.01.23.12650	OBAT	Selesai Proses Pemuatan	2023/01/13 11:10:24	2023/01/13 11:12:13	13389305000119
WO.1007.01.23.12650	OBAT	Berangkat dari Lokasi Pemuatan	2023/01/13 11:30:45	2023/01/13 16:07:13	13389305000119
WO.1007.01.23.12650	OBAT	Tiba Dilokasi Pembongkaran	2023/01/13 16:10:23	2023/01/13 16:11:36	13389305000119
WO.1007.01.23.12650	OBAT	Proses Pembongkaran	2023/01/13 18:11:36	2023/01/13 21:33:47	13389305000119
WO.1007.01.23.12650	OBAT	Selesai Proses Pembongkaran	2023/01/13 21:40:36	2023/01/13 21:44:26	13389305000119
WO.1007.01.23.12650	OBAT	Berangkat ke Pool	2023/01/13 21:51:36	2023/01/14 06:11:36	13389305000119
WO.1007.01.23.12650	OBAT	Tiba di Pool	2023/01/14 06:14:24	2023/01/14 06:15:31	Admin DKI
WO.1007.01.23.12650	OBAT	Work Order Selesai	2023/01/14 06:15:49	2023/01/14 06:18:31	Admin DKI
WO.1007.02.23.12814	Battery	Work Order Dibuat	2023/01/03 08:14:08	2023/01/03 08:14:43	Admin DKI
WO.1007.02.23.12814	Battery	Work Order Diterima	2023/01/03 08:15:24	2023/01/03 08:17:59	122241194
WO.1007.02.23.12814	Battery	Verifikasi Work Order	2023/01/03 08:20:45	2023/01/03 08:25:04	Admin DKI
WO.1007.02.23.12814	Battery	Uang Jalan Diterima	2023/01/03 08:28:35	2023/01/03 08:32:46	Admin DKI
WO.1007.02.23.12814	Battery	Tiba Dilokasi Pemuatan	2023/01/03 11:34:25	2023/01/03 11:38:29	122241194
WO.1007.02.23.12814	Battery	Proses Pemuatan	2023/01/03 13:25:46	2023/01/03 14:54:36	122241194
WO.1007.02.23.12814	Battery	Selesai Proses Pemuatan	2023/01/03 14:57:44	2023/01/03 15:00:56	122241194

WO.1007.02.23.12814	Battery	Berangkat dari Lokasi Pemuatan	2023/01/03 15:02:34	2023/01/03 16:15:25	122241194
WO.1007.02.23.12814	Battery	Tiba Dilokasi Pembongkaran	2023/01/04 06:18:05	2023/01/04 06:19:08	122241194
WO.1007.02.23.12814	Battery	Proses Pembongkaran	2023/01/04 08:19:08	2023/01/04 10:20:33	122241194
WO.1007.02.23.12814	Battery	Selesai Proses Pembongkaran	2023/01/04 10:22:33	2023/01/04 10:25:43	122241194
WO.1007.02.23.12814	Battery	Berangkat ke Pool	2023/01/04 10:27:53	2023/01/04 16:30:50	122241194
WO.1007.02.23.12814	Battery	Tiba di Pool	2023/01/04 16:32:43	2023/01/04 16:35:37	Admin DKI
WO.1007.02.23.12814	Battery	Work Order Selesai	2023/01/04 16:58:42	2023/01/04 17:00:37	Admin DKI
WO.1007.02.23.12867	Sembako	Work Order Dibuat	2023/02/10 03:24:16	2023/02/10 03:26:15	Admin DKI
WO.1007.02.23.12867	Sembako	Work Order Diterima	2023/02/10 03:29:36	2023/02/10 03:34:52	000000000666
WO.1007.02.23.12867	Sembako	Verifikasi Work Order	2023/02/10 05:35:52	2023/02/10 05:42:58	Admin DKI
WO.1007.02.23.12867	Sembako	Uang Jalan Diterima	2023/02/10 05:46:26	2023/02/10 05:49:15	Admin DKI
WO.1007.02.23.12867	Sembako	Tiba Dilokasi Pemuatan	2023/02/10 07:27:15	2023/02/10 12:27:17	000000000666
WO.1007.02.23.12867	Sembako	Proses Pemuatan	2023/02/10 14:15:51	2023/02/10 16:24:19	000000000666
WO.1007.02.23.12867	Sembako	Selesai Proses Pemuatan	2023/02/10 16:27:14	2023/02/10 16:29:26	000000000666
WO.1007.02.23.12867	Sembako	Berangkat dari Lokasi Pemuatan	2023/02/10 18:31:18	2023/02/10 23:27:26	000000000666
WO.1007.02.23.12867	Sembako	Tiba Dilokasi Pembongkaran	2023/02/10 23:29:24	2023/02/11 01:39:26	000000000666
WO.1007.02.23.12867	Sembako	Proses Pembongkaran	2023/02/11 03:39:26	2023/02/11 05:48:46	000000000666
WO.1007.02.23.12867	Sembako	Selesai Proses Pembongkaran	2023/02/11 05:50:46	2023/02/11 05:55:49	000000000666
WO.1007.02.23.12867	Sembako	Berangkat ke Pool	2023/02/11 06:02:49	2023/02/11 11:39:49	000000000666
WO.1007.02.23.12867	Sembako	Tiba di Pool	2023/02/11 11:40:33	2023/02/11 11:50:58	Admin DKI
WO.1007.02.23.12867	Sembako	Work Order Selesai	2023/02/11 11:53:48	2023/02/11 11:55:26	Admin DKI
WO.1007.02.23.12903	Bahan Kimia	Work Order Dibuat	2023/02/14 02:00:29	2023/02/14 02:01:49	Admin DKI
WO.1007.02.23.12903	Bahan Kimia	Work Order Diterima	2023/02/14 03:01:49	2023/02/14 03:03:10	660913440214
WO.1007.02.23.12903	Bahan Kimia	Verifikasi Work Order	2023/02/14 03:03:10	2023/02/14 03:06:17	Admin DKI

WO.1007.02.23.12903	Bahan Kimia	Uang Jalan Diterima	2023/02/14 03:15:34	2023/02/14 03:37:48	Admin DKI
WO.1007.02.23.12903	Bahan Kimia	Tiba Dilokasi Pemuatan	2023/02/14 06:22:37	2023/02/14 14:25:37	660913440214
WO.1007.02.23.12903	Bahan Kimia	Proses Pemuatan	2023/02/14 15:37:12	2023/02/14 18:37:53	660913440214
WO.1007.02.23.12903	Bahan Kimia	Selesai Proses Pemuatan	2023/02/14 18:37:53	2023/02/14 18:40:59	660913440214
WO.1007.02.23.12903	Bahan Kimia	Berangkat dari Lokasi Pemuatan	2023/02/14 20:43:25	2023/02/15 04:38:02	660913440214
WO.1007.02.23.12903	Bahan Kimia	Tiba Dilokasi Pembongkaran	2023/02/15 04:48:02	2023/02/15 04:50:35	660913440214
WO.1007.02.23.12903	Bahan Kimia	Proses Pembongkaran	2023/02/15 08:34:33	2023/02/15 11:43:14	660913440214
WO.1007.02.23.12903	Bahan Kimia	Selesai Proses Pembongkaran	2023/02/15 11:47:14	2023/02/15 11:50:27	660913440214
WO.1007.02.23.12903	Bahan Kimia	Berangkat ke Pool	2023/02/15 11:54:53	2023/02/15 19:39:32	660913440214
WO.1007.02.23.12903	Bahan Kimia	Tiba di Pool	2023/02/15 19:49:32	2023/02/15 20:03:48	Admin DKI
WO.1007.02.23.12903	Bahan Kimia	Work Order Selesai	2023/02/15 20:04:48	2023/02/15 20:05:25	Admin DKI
WO.1007.02.23.12904	Sembako	Work Order Dibuat	2023/02/10 03:24:16	2023/02/10 03:26:15	Admin DKI
WO.1007.02.23.12904	Sembako	Work Order Diterima	2023/02/10 03:29:36	2023/02/10 03:34:52	750713441042
WO.1007.02.23.12904	Sembako	Verifikasi Work Order	2023/02/10 05:35:52	2023/02/10 05:42:58	Admin DKI
WO.1007.02.23.12904	Sembako	Uang Jalan Diterima	2023/02/10 05:46:26	2023/02/10 05:49:15	Admin DKI
WO.1007.02.23.12904	Sembako	Tiba Dilokasi Pemuatan	2023/02/10 07:27:15	2023/02/10 12:27:17	750713441042
WO.1007.02.23.12904	Sembako	Proses Pemuatan	2023/02/10 14:15:51	2023/02/10 16:24:19	750713441042
WO.1007.02.23.12904	Sembako	Selesai Proses Pemuatan	2023/02/10 16:27:14	2023/02/10 16:29:26	750713441042
WO.1007.02.23.12904	Sembako	Berangkat dari Lokasi Pemuatan	2023/02/10 18:31:18	2023/02/10 23:27:26	750713441042
WO.1007.02.23.12904	Sembako	Tiba Dilokasi Pembongkaran	2023/02/10 23:29:24	2023/02/11 01:39:26	750713441042
WO.1007.02.23.12904	Sembako	Proses Pembongkaran	2023/02/11 03:39:26	2023/02/11 05:48:46	750713441042
WO.1007.02.23.12904	Sembako	Selesai Proses Pembongkaran	2023/02/11 05:50:46	2023/02/11 05:55:49	750713441042
WO.1007.02.23.12904	Sembako	Berangkat ke Pool	2023/02/11 06:02:49	2023/02/11 11:39:49	750713441042
WO.1007.02.23.12904	Sembako	Tiba di Pool	2023/02/11 11:40:33	2023/02/11 11:50:58	Admin DKI

WO.1007.02.23.12904	Sembako	Work Order Selesai	2023/02/11 11:53:48	2023/02/11 11:55:26	Admin DKI
WO.1007.06.23.13603	OBAT	Work Order Dibuat	2023/01/12 13:55:08	2023/01/12 13:59:08	Admin DKI
WO.1007.06.23.13603	OBAT	Work Order Diterima	2023/01/12 14:08:31	2023/01/12 14:10:37	1221180804702
WO.1007.06.23.13603	OBAT	Verifikasi Work Order	2023/01/12 14:45:43	2023/01/12 14:48:41	Admin DKI
WO.1007.06.23.13603	OBAT	Uang Jalan Diterima	2023/01/12 14:50:37	2023/01/12 14:53:35	Admin DKI
WO.1007.06.23.13603	OBAT	Tiba Dilokasi Pemuatan	2023/01/12 17:57:56	2023/01/13 05:40:37	1221180804702
WO.1007.06.23.13603	OBAT	Proses Pemuatan	2023/01/13 08:05:47	2023/01/13 11:07:13	1221180804702
WO.1007.06.23.13603	OBAT	Selesai Proses Pemuatan	2023/01/13 11:10:24	2023/01/13 11:12:13	1221180804702
WO.1007.06.23.13603	OBAT	Berangkat dari Lokasi Pemuatan	2023/01/13 11:30:45	2023/01/13 16:07:13	1221180804702
WO.1007.06.23.13603	OBAT	Tiba Dilokasi Pembongkaran	2023/01/13 16:10:23	2023/01/13 16:11:36	1221180804702
WO.1007.06.23.13603	OBAT	Proses Pembongkaran	2023/01/13 18:11:36	2023/01/13 21:33:47	1221180804702
WO.1007.06.23.13603	OBAT	Selesai Proses Pembongkaran	2023/01/13 21:40:36	2023/01/13 21:44:26	1221180804702
WO.1007.06.23.13603	OBAT	Berangkat ke Pool	2023/01/13 21:51:36	2023/01/14 06:11:36	1221180804702
WO.1007.06.23.13603	OBAT	Tiba di Pool	2023/01/14 06:14:24	2023/01/14 06:15:31	Admin DKI
WO.1007.06.23.13603	OBAT	Work Order Selesai	2023/01/14 06:15:49	2023/01/14 06:18:31	Admin DKI
WO.1007.10.23.14187	Beras	Work Order Dibuat	2023/10/31 13:47:53	2023/10/31 13:49:36	Admin DKI
WO.1007.10.23.14187	Beras	Work Order Diterima	2023/10/31 13:52:17	2023/10/31 14:05:23	660913440214
WO.1007.10.23.14187	Beras	Verifikasi Work Order	2023/10/31 16:07:31	2023/10/31 16:16:22	Admin DKI
WO.1007.10.23.14187	Beras	Uang Jalan Diterima	2023/10/31 16:49:59	2023/10/31 16:53:23	Admin DKI
WO.1007.10.23.14187	Beras	Tiba Dilokasi Pemuatan	2023/10/31 16:55:37	2023/10/31 21:38:21	660913440214
WO.1007.10.23.14187	Beras	Proses Pemuatan	2023/10/31 23:23:51	2023/11/01 02:41:49	660913440214
WO.1007.10.23.14187	Beras	Selesai Proses Pemuatan	2023/11/01 00:57:22	2023/11/01 01:00:38	660913440214
WO.1007.10.23.14187	Beras	Berangkat dari Lokasi Pemuatan	2023/11/01 01:16:00	2023/11/01 08:27:32	660913440214
WO.1007.10.23.14187	Beras	Tiba Dilokasi Pembongkaran	2023/11/01 08:29:32	2023/11/01 08:37:12	660913440214

WO.1007.10.23.14187	Beras	Proses Pembongkaran	2023/11/01 09:37:12	2023/11/01 11:22:46	660913440214
WO.1007.10.23.14187	Beras	Selesai Proses Pembongkaran	2023/11/01 11:23:12	2023/11/01 11:25:38	660913440214
WO.1007.10.23.14187	Beras	Berangkat ke Pool	2023/11/01 12:03:23	2023/11/01 21:37:12	Admin DKI
WO.1007.10.23.14187	Beras	Tiba di Pool	2023/11/01 21:40:43	2023/11/01 21:47:55	Admin DKI
WO.1007.10.23.14187	Beras	Work Order Selesai	2023/11/01 21:57:55	2023/11/01 22:00:32	Admin DKI
WO.1007.11.23.14238	OBAT	Work Order Dibuat	2023/01/12 13:55:08	2023/01/12 13:59:08	Admin DKI
WO.1007.11.23.14238	OBAT	Work Order Diterima	2023/01/12 14:08:31	2023/01/12 14:10:37	1221180804702
WO.1007.11.23.14238	OBAT	Verifikasi Work Order	2023/01/12 14:45:43	2023/01/12 14:48:41	Admin DKI
WO.1007.11.23.14238	OBAT	Uang Jalan Diterima	2023/01/12 14:50:37	2023/01/12 14:53:35	Admin DKI
WO.1007.11.23.14238	OBAT	Tiba Dilokasi Pemuatan	2023/01/12 17:57:56	2023/01/13 05:40:37	1221180804702
WO.1007.11.23.14238	OBAT	Proses Pemuatan	2023/01/13 08:05:47	2023/01/13 11:07:13	1221180804702
WO.1007.11.23.14238	OBAT	Selesai Proses Pemuatan	2023/01/13 11:10:24	2023/01/13 11:12:13	1221180804702
WO.1007.11.23.14238	OBAT	Berangkat dari Lokasi Pemuatan	2023/01/13 11:30:45	2023/01/13 16:07:13	1221180804702
WO.1007.11.23.14238	OBAT	Tiba Dilokasi Pembongkaran	2023/01/13 16:10:23	2023/01/13 16:11:36	1221180804702
WO.1007.11.23.14238	OBAT	Proses Pembongkaran	2023/01/13 18:11:36	2023/01/13 21:33:47	1221180804702
WO.1007.11.23.14238	OBAT	Selesai Proses Pembongkaran	2023/01/13 21:40:36	2023/01/13 21:44:26	1221180804702
WO.1007.11.23.14238	OBAT	Berangkat ke Pool	2023/01/13 21:51:36	2023/01/14 06:11:36	Admin DKI
WO.1007.11.23.14238	OBAT	Tiba di Pool	2023/01/14 06:14:24	2023/01/14 06:15:31	Admin DKI
WO.1007.11.23.14238	OBAT	Work Order Selesai	2023/01/14 06:15:49	2023/01/14 06:18:31	Admin DKI
WO.1007.12.22.12589	OBAT	Verifikasi Work Order	2023/01/11 08:03:09	2023/01/11 08:03:15	Admin DKI
WO.1007.12.22.12589	OBAT	Uang Jalan Diterima	2023/01/11 08:03:15	2023/01/11 08:03:15	Admin DKI
WO.1007.12.22.12589	OBAT	Tiba Dilokasi Pemuatan	2023/01/11 08:43:06	2023/01/11 08:43:10	1205171102918
WO.1007.12.22.12589	OBAT	Proses Pemuatan	2023/01/11 08:43:10	2023/01/11 08:43:14	1205171102918
WO.1007.12.22.12589	OBAT	Selesai Proses Pemuatan	2023/01/11 08:43:14	2023/01/11 08:43:41	1205171102918

WO.1007.12.22.12589	OBAT	Berangkat dari Lokasi Pemuatan	2023/01/11 08:43:41	2023/01/11 08:43:46	1205171102918
WO.1007.12.22.12589	OBAT	Tiba Dilokasi Pembongkaran	2023/01/11 08:43:46	2023/01/11 08:43:50	1205171102918
WO.1007.12.22.12589	OBAT	Proses Pembongkaran	2023/01/11 08:43:50	2023/01/11 08:44:28	1205171102918
WO.1007.12.22.12589	OBAT	Selesai Proses Pembongkaran	2023/01/11 08:44:28	2023/01/11 08:44:37	1205171102918
WO.1007.12.22.12589	OBAT	Berangkat ke Pool	2023/01/11 08:44:37	2023/01/11 08:44:37	1205171102918
WO.1007.12.22.12589	OBAT	Tiba di Pool	2023/01/11 10:09:01	2023/01/11 10:09:20	Admin DKI
WO.1007.12.22.12589	OBAT	Work Order Selesai	2023/01/11 10:09:20	2023/01/11 10:09:20	Admin DKI
WO.1007.12.23.14431	ELEKTRONIK	Work Order Dibuat	2023/12/04 09:19:25	2023/12/04 09:19:52	Admin DKI
WO.1007.12.23.14431	ELEKTRONIK	Work Order Diterima	2023/12/04 09:19:52	2023/12/04 09:20:09	840412055115
WO.1007.12.23.14431	ELEKTRONIK	Verifikasi Work Order	2023/12/04 09:20:09	2023/12/04 09:20:14	Admin DKI
WO.1007.12.23.14431	ELEKTRONIK	Uang Jalan Diterima	2023/12/04 09:20:14	2023/12/04 09:20:14	Admin DKI
WO.1007.12.23.14441	TIMAH	Work Order Dibuat	2023/12/04 14:58:13	2023/12/04 14:58:24	Admin DKI
WO.1007.12.23.14441	TIMAH	Work Order Diterima	2023/12/04 14:58:24	2023/12/04 14:58:36	660913440214
WO.1007.12.23.14441	TIMAH	Verifikasi Work Order	2023/12/04 14:58:36	2023/12/04 14:58:41	Admin DKI
WO.1007.12.23.14441	TIMAH	Uang Jalan Diterima	2023/12/04 14:58:41	2023/12/04 14:58:48	Admin DKI
WO.1007.12.23.14441	TIMAH	Tiba Dilokasi Pemuatan	2023/12/04 14:58:48	2023/12/04 14:58:48	660913440214