A Process Mining Framework for Continual Service Improvements

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Preface

The decision to pursue a postgraduate degree was a dilemma to leaving my family, friends, and a well-paying job as a software engineer. On January 23, 2021, I took my one-way flight to The Netherlands. Having booked my Masters colloquium on January 23, 2023, I can confidently preach, *'Take the risk or lose the change'*. From honing my business and technology expertise to building a network of kind and inspiring people, every day for the past two years has been a learning for life and a great exposure to unthought opportunities.

Hereby, presenting the master thesis *"A Process Mining Framework for Continual Service Improvements"*, carried out in collaboration with Deloitte Netherlands from June 2022 to January 2023. I want to express immense gratitude to the following people who have inspired and motivated me throughout this research.

- Firstly, my university supervisors, Faiza Bukhsh and Maria Iacob, for their time and outstanding guidance, both academically and morally.
- My Deloitte supervisors, Quintin Hessing and Salih Kalkavan, for their valuable, constructive suggestions and willingness to dedicate their time during the planning and execution of this research.
- All the experts that partook in this research for their time and contributions. Conversations with them have widened my horizon with the process mining practice.
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- Special thanks to Gabriela Galic, Lukas Bielmeier, Jainish Korant, Kandhan Sekar, and Goutham Baskaran for going the extra mile with their support.

A special acknowledgement to *Deloitte* for the opportunity as a graduate intern for their Enterprise Service and Process Management Team that led to a valuable network and incredible opportunities. I also owe big time to my friends and colleagues from the University of Twente for all the fun times, lifetime experiences and learnings.

I would like to extend my gratitude to my amma for her endless phone calls and love, appa for his constant dad jokes and wisdom, Prasanna and Pavi for their virtual support, and Riyaan for being my pill of happiness, especially during tough times. Thanks to Pavi, Anusha, and Karu for keeping me sane no matter the distance or time that separates us. Special thanks to my partner, Boon, for sticking with me through thick and thin. *I love you all indefinitely.*

Last but not least, I want to thank me for writing and you for reading this report. Trust that it leaves you with valuable knowledge in return for your time.

Charumathi Palanikumar
Amsterdam, January 20, 2023.

Abstract

Process mining enables data-driven insights into the knowledge of the business processes of organizations using event logs through various techniques and algorithms. Several literature studies reveal the advantages of using process mining techniques in service process analysis and improvement initiatives. Nevertheless, there is a lack of framework providing explicit guidelines on systematically leveraging process mining in continual service improvements. Addressing this issue, Process Mining for Continual Service Improvements (PM4CSI) has been designed and developed to support the systematic use of process mining techniques aligned with the seven steps of ITIL (Information Technology Infrastructure Library) Continual Improvement Model. Design Science Research Methodology has been followed in developing the PM4CSI framework by iteratively collaborating with the experts in Information Technology Service Management (ITSM) and process mining, and validated by conducting demonstrations, interviews, and surveys with industry experts and case studies with real organizational process-related data. Validation of the PM4CSI framework revealed the usefulness of the framework as a guideline to support ITSM practitioners in service process enhancements. The framework offers systematic and structured guidelines by leveraging process mining techniques in continual improvement initiatives. Therefore, PM4CSI framework can help increase the effectiveness and efficiency of ITIL Continual Service Improvement activities, thus closing the gap between process mining and continual service improvements.

Keywords: *ITIL Continual Improvement Framework, Process Mining, IT Service Management, Framework, Methodology, Case Study, Survey*

Executive summary

Introduction

In the IT Service Management (ITSM) industry, a considerable gap is usually seen between the initial process design and the actual processes. Such a process gap creates sub-optimal processes for businesses, leading to a low adoption rate of the supporting system. As a result, business users and service management teams develop parallel processes and frictions. These actions lead to poor compliance, inefficient processes, and customer satisfaction. Consequently, there is an impact on cost, time, and quality of operations. In the face of the pandemic, which increased remote work, ITSM ticket volumes have seen over 35% increase in the past year. A significant hike in cost and ticket handling time has been seen in the ITSM sector.

With the advent of numerous Process-Aware Information Systems (PAISs) enabling IT services such as *ServiceNow* registering the service operation transactions, it is essential to take advantage of the explosion of process-oriented data from such information systems to optimize the process. Several data-driven approaches have been adopted in the field of service improvements. Process mining acting between process modeling and analysis, on the one hand, and between data mining and computational business intelligence, on the other hand, can enable management trends related to service process improvements. A significant number of existing literature reveals the success of leveraging process mining techniques in assessing and improving service processes. Nevertheless, there is a lack of knowledge on a standardized method guiding ITSM practitioners on how and when to use process mining techniques to perform ITIL Continual Improvement activities effectively. Specifically, there has been no academic research on bridging such gaps between process mining and ITSM process improvements.

Design Science Research

Wieringa's Design Science Research Methodology (DSRM) was followed to develop the PM4CSI framework. Initially, informal interviews were conducted to understand the challenges in the ITSM industry. Then, research questions were formulated to perform the research through a literature review and expert interviews to develop the artifact. A literature review was conducted following a systematic literature review approach to understand the state-of-the-art of process mining application in ITSM sphere. Consequently, it has been found that ITIL is the most popular and de-facto standard for service improvements and that no academic research followed a standardized framework establishing explicit guidelines on systematically leveraging process mining in continual service improvements. Hence, a process mining approach has been developed by merging the approaches taken by various researchers from the literature review. The developed process mining approach was then mapped to the seven steps of the ITIL Continual Improvement Model.

To avoid researcher bias and tackle ambiguity of the framework characteristics such as inputs, output, stakeholders and activities of each phase, framework refinement interviews were conducted with thirteen process mining and ITSM experts over two rounds to ensure data saturation. Subsequently, a refined version of PM4CSI has been designed and developed. PM4CSI framework is a three-part framework comprising of a high-level graphical abstract , a detailed graphical overview of the framework, and comprehensive explanation of the PM4CSI phases in forms of activity flow diagrams, tables and textual guidelines. The PM4CSI comprises nine phases in the central flow: *Project Initiation, Data Ingestion, Data Preparation, Process Discovery and Analysis, Deliver Insights, Improvement Planning, Process Improvement, Measure Results, Support Continual Improvement*. Additionally, the framework has a layer showing the critical stakeholder as the leading role responsible for each phase of the PM4CSI. Since some duties in each phase are better performed by a specific role than another, there is a particular lead role responsible for each phase. Although each stage is tied to a particular role, the tasks at each phase require a collaborative effort of members from all of these roles and utilizing the expertise provided by each of them.

Finally, the framework was validated through expert opinions and case studies. Expert opinions followed a demonstration of the PM4CSI framework to seven industry experts. To critically evaluate the relevance, practicality, usability and utility of the PM4CSI framework, survey questions were meticulously formulated based on the Technology Acceptance Model 2 (TAM2) constructs - perceived ease-of-use, perceived usefulness, and intention to use. Overall, all the constructs were positively rated by the industry experts. While the ex-ante interviews during framework refinement prove the validity of the PM4CSI framework, these ex-post evaluation interviews confirm the potential and utility of the PM4CSI to be adopted in practice and for application in the real-world problem context. However, the framework requires conceptual knowledge of this research's domains. Two case studies with three different process mining market tools were conducted by applying the PM4CSI and observing the effects to check the validity and generalizability of the findings, along with evaluating the practicality and tool independence nature of the PM4CSI framework. The results confirmed and satisfied the utility, usability and tool-independent applicability of the PM4CSI. Thus, with the PM4CSI framework, challenges in ITSM can be tackled in a fact-based approach by leveraging process mining techniques in the continual improvement initiatives.

Conclusion

PM4CSI supports organizations and ITSM practitioners to assess and improve their ITSM operations by complementing their ITIL Continual Improvement initiative. Thus, with the PM4CSI framework, ITSM practitioners or organizations aiming to improve the ITSM processes have a standardized operating framework guiding how and when to use process mining techniques for continual service improvements. PM4CSI has not been developed to replace the ITIL Continual Improvement Model. Instead, the PM4CSI framework should be seen as an approach to complement continual service improvements using process mining techniques. PM4CSI is a process-independent, tool-independent, comprehensive, domain-relevant framework that accounts for business knowledge and supports iterations through the improvement initiative. For these reasons, ITSM continual improvement and process mining experts find the PM4CSI framework as beneficial guidelines to assess and improve ITSM operations. Thus, PM4CSI satisfies the objective of this research.

To conclude, the contribution of this research are as follows:

- For the scientific community, this research proposes a process mining framework for continual service improvements. It illustrates when and how process mining techniques can be applied in service improvement initiatives. Thus, this research adds value to ITSM

and Process Mining fields by integrating the process mining approach into ITIL Continual Improvement Model.
- In practice, the research provides promising guidelines for continually assessing and improving ITSM operations in a fact-based and data-driven approach. Besides guidelines, this research offers a detailed approach to what roles are required to achieve value milestones in a process mining improvement project. ITSM practitioners generally perform Continual Service Improvement initiatives, and PM4CSI complement these assessments.

One major limitation for practice is that the detailed level of the framework has been designed using Bizagi Modeller. Non-technical persons might find the artifact challenging to understand at the first glimpse of the PM4CSI framework. However, comprehensive guidelines were provided in textual and table formats for precise documentation.

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List of Abbreviations

BPI Business Process Improvements.

BPM Business Process Management.

CMMI Capability Maturity Model Integration.

CMMI-SVC Capability Maturity Model Integrated for Services.

COBIT Control Objectives for Information and related Technology.

CPM Corporate Performance Management.

CRM Customer Relationship Management.

DSRM Design Science Research Methodology.

ERP Enterprise Resource Planning.

ESPM Enterprise Service and Process Management.

HPSM HP Service Management.

IaaS Infrastructure as a Service.

IT Information Technology.

ITIL Information Technology Infrastructure Library.

ITSM Information Technology Service Management.

KPIs Key Performance Indicators.

LR Literature Review.

MOF Microsoft Operations Framework.

PAIS Process Aware Information System.

PM4CSI Process Mining for Continual Service Improvement.

PPIs Process Performance Indicators.

SCM Supply Chain Management.

SLA Service Level Agreements.

SLR Systematic Literature Review.

SMEs Subject Matter Experts.

SSLR Semi-Systematic Literature Review.

TQM Total Quality Management.

WfMS Workflow Management Systems.

XES eXtensible Event Stream.

Chapter 1

Introduction

This chapter introduces the conducted research. Firstly, the research context is presented, followed by the problem statement, which gives an overview of the issue discussed in this paper, its background and whom it affects. Then, the research objectives and scope are introduced. Lastly, the research questions that guide this research are introduced to the readers.

1.1 Research Context

Services are everywhere. It is the primary means for businesses to add value for themselves and their clients. Organizations must manage the delivery of services to support users in performing their business activities. The services sector has seen massive growth in recent decades. Service Science has emerged as a discipline that incorporates not only technology but also the people and processes that collaboratively work to deliver services, expanding on the term "service" in the deed, process, and performance sense [1]. According to the World Trade Organization, services are the most dynamic and significant component of both developing and developed economies [2]. In the last few decades, Information Technology (IT) has become a vital part of our daily life at home, school, work, travel and everywhere. An IT service is a set of services that are provided by an IT system and/or IT department to support business processes. In specific cases, IT services are the output of one or more IT service processes [3]. Braun et al. presented a metamodel for IT services as shown in Figure 1.1, which describes the alignment of IT service within an enterprise.

Gartner estimated the global market for IT services to grow by 6.2% in 2022 and 9.1% in next four years. In the Netherlands, the service industry contributes 69.53% of the GDP of the country (Source: Statista 2022). Consequently, the service sector employs the majority of the workforce of the country. Such statistics help us to foresee that enterprise software and IT services will continue to exhibit strong growth on a global scale. Additionally, with an increasing trend in digital transformation, almost all services are IT-enabled. The key objective for service providers is to characterize, manage, and deliver IT services to support the business goals and needs of customers, commonly in IT operations [4]. On average, over 70% of the IT expenditure is spent on operating and maintenance activities to keep IT service ongoing [5]. Hence, developing, enhancing, and expanding IT service management capabilities will be highly beneficial for organizations to possess a competitive advantage by managing the needs of their end users.

Today, businesses depend on services and the IT service providers need to deliver them rapidly,

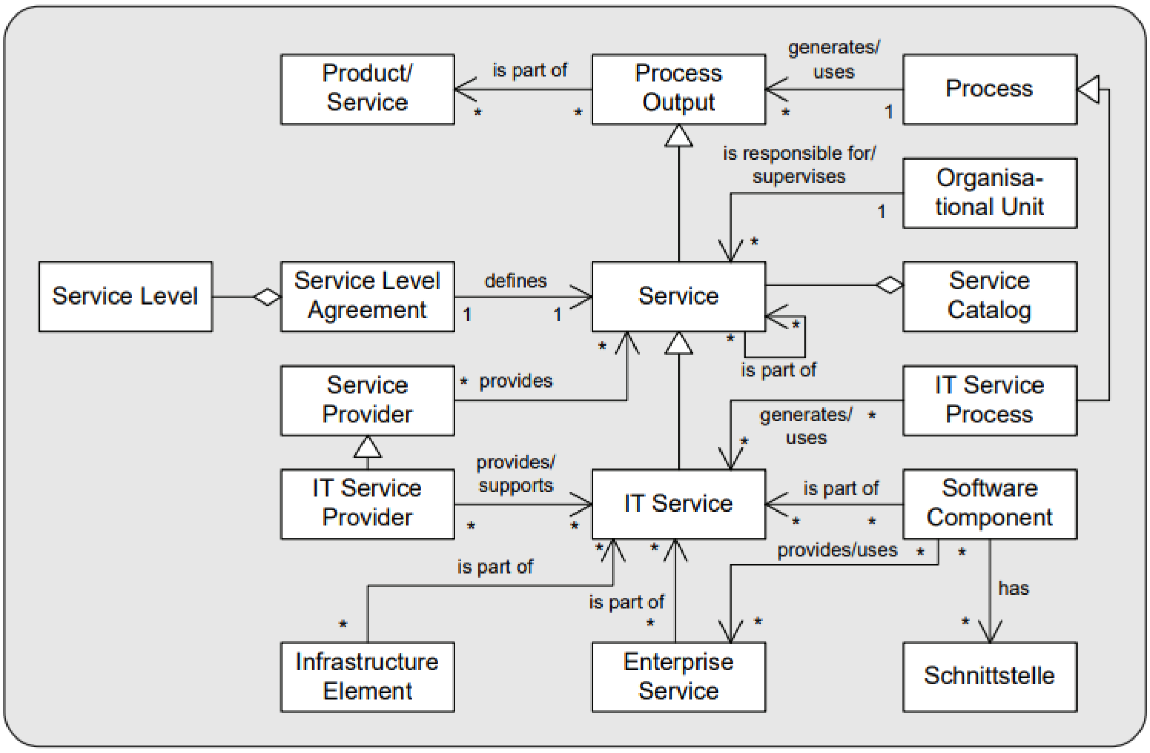

Figure 1.1: UML Notation of IT Services [3]

with low cost and high-quality [6]. Core business processes require strong support by improving the quality of services for users and customers while reducing operational costs [7]. With the advent of numerous Process-Aware Information Systems (PAISs) enabling IT services, the service operations are digitally registered, with every transaction being tracked by these systems. According to estimates, in 10 minutes today, the same amount of data is produced from the stone age till 2013 [8]. The explosion of such process-oriented data today has increased the interest in exploiting process-related data to interpret how the business processes run [9]. New opportunities for understanding and improving processes are provided by analyzing such an available "ocean of data". Process mining emerged as a research discipline to use the fine-granular process data [10]. Instead of redesigning the business process based on assumptions, organizations can use process mining to reveal what is happening in their actual processes [11]. Process mining may therefore scale with excellent productivity and confidence while simultaneously identifying the underlying causes of bottlenecks and optimizing their resources. Thus, it has seen increased adoption in enterprises in recent years, becoming an integral part of their daily business process management.

Process mining acting between process modeling and analysis, on the one hand, and between data mining and computational business intelligence, on the other hand, can enable management trends related to service process improvements. One of the service management strategies that has seen a vast increase in adoption is the Information Technology Infrastructure Library (ITIL). ITIL uses a system of intricate practices for IT activities like IT asset management and IT service management, which concentrate on matching IT services with business requirements [2]. Initially, the Central Computer and Telecommunications Agency of the UK government established ITIL in the 1980s in response to government agencies and private-sector organizations developing their IT management strategies. With the branching out of IT across almost every sector today, ITIL can benefit any organization worldwide, in all sectors and industries, that provides an IT service management service or product. Through its seven-step *Continual*

Improvement Model, formerly known as *Continual Service Improvement*, and which can be used as a high-level guide to support improvement initiatives, the ITIL framework also offers a structure and direction for continuously improving the organization's service practices. The reason Axelos renamed the ITIL V3/2011 Continual Service Improvement (CSI) process to Continual Improvement in ITIL 4 is that the 'improvement' can cover more than provided IT services, i.e., many elements of Information Technology Service Management (ITSM) including services, operations, outcomes, and experiences [2]. Putting a strong focus on customer value, ITIL V4's Continual Improvement Model ensures that process improvement efforts can be linked to the organization's vision.

Only one research shows how Process Mining can check compliance of as-is processes with to-be processes through a Continuous Process Improvement reference model, followed by the ITIL V3/2011 seven-step Continual Service Improvement procedure [12]. Nevertheless, there needs to be a structured method guiding when and how to use process mining techniques to perform ITIL Continual Improvement activities effectively. This results in the following research objective:

To develop a process mining framework with elements such as pre-requisites, roles required and output, that supports organizations adopting the ITILV4/2019 Continual Improvement Model to perform process improvement activities using process mining techniques effectively.

Duly, Process Mining for Continual Service Improvement (PM4CSI) is developed to guide ITSM practitioners in effectively implementing their improvement projects by using process mining techniques. The PM4CSI has been designed by creating a process mining approach combining the existing practices and methodologies to suit the Continual Improvement related activities. PM4CSI, thus, offers a mapping to use process mining techniques within the service improvements projects by ITSM practitioners. Therefore, this thesis closes the gap between Process Mining and Information Technology Infrastructure Library (ITIL) Continual Improvement practices.

Following the Design Science Research Methodology (DSRM) by Wieringa [13], the initial version of PM4CSI was developed by considering already existing process mining approaches and methodologies found in the literature as a basis and mapping the phases to the steps of ITIL Continual Improvement Model. The first version of PM4CSI has been adapted by gathering insights from domain experts through two series of semi-structured interviews. The validity of the refined version of PM4CSI has been evaluated through organizational case studies and validation sessions with both ITIL and process mining experts. The utility and usability of PM4CSI have been assessed through a survey to the domain experts that partook in the case study and validation sessions. The evaluation shows that PM4CSI is helpful as a guide to more effectively perform improvement initiatives based on ITIL Continual Improvement Model by leveraging process mining techniques.

1.2 Problem Statement

This section presents a brief introduction to ITSM, followed by challenges in the ITSM operations and the rationale behind using process mining in ITSM sphere.

1.2.1 Information Technology Service Management

Setting up IT service management processes enables organizations to improve the quality of service and ensure greater compliance by standardized processes. It focuses on IT operations such as delivery and support of services. In simple words, ITSM is how IT department manages the end-to-end delivery of IT services to end-users. Business processes are at the core of ITSM. It is a strategy for IT services delivery and support to an enterprise, its customers, employees, and other business stakeholders. Today, these operations are carried out efficiently by the helpdesk using popular ITSM tools available in the market, such as Salesforce, ServiceNow, and HP Service Management.

ITSM ensures that tickets submitted by end users are serviced and resolved within the agreed resolution times. Incapability to meet on such agreed times induces heavy penalties on the service provider. A service level clock is used to measure the service resolution time and is associated with every ticket. Each ticket has two states - *pause* and *resume* [14]. Based on business criticality, as a part of Service Level Agreements (SLA), the service provider and the client agree on a service level resolution time for every category of tickets [2]. ITSM helps firms to become responsive and efficient by streamlining operations and reducing service requests through automation. It influences customer experience and employee productivity. Consequently, overall user satisfaction directly translates to positive business outcomes. The benefits brought by ITSM to IT services and support are as follows: increased efficiency, consistent service delivery, reduced downtime, service-based incident management, reduction in operational costs, and high accountability. Section 3.1.2 will introduce a detailed overview of ITSM and best practices.

1.2.2 Challenges in ITSM

After interviewing ITSM domain experts to ensure practical challenges faced by ITSM industry, the below challenges in ITSM processes are identified. Table A.2 shows the experts interviewed to understand typical challenges in ITSM. According to the ITIL framework, service operations within IT management includes the following processes [15]:

- Event Management
- Incident Management
- Problem Management
- Change Control and Release Management
- Request Fulfillment
- Access Management

Usually, in the ITSM industry, a considerable gap is seen between the initial process design and the actual processes. Such a process gap creates sub-optimal processes for businesses, leading to a low adoption rate of the supporting system. As a result, business users and service management teams develop parallel processes and frictions. These actions lead to poor compliance, inefficient processes, and customer dissatisfaction. Consequently, there is an impact on cost, time, and quality of operations. In the face of the pandemic, which increased remote work, ITSM ticket volumes have seen over 35% increase in the past year. A significant hike in cost and ticket handling time has been seen in ITSM sector (Source: BMC Blog).

Despite numerous benefits contributed by ITSM, many organizations still face challenges in day-to-day business activities. Typical challenges in ITSM processes are as follows: *delayed resolutions, inefficient approval process, multiple hops and Ping-Pong behaviour, lack of incident-problem mapping, unresolved tickets, missing customer inputs, categorization quality, manual effort vs automation potentials, unrealistic SLA*, and can be seen in figure 1.2.

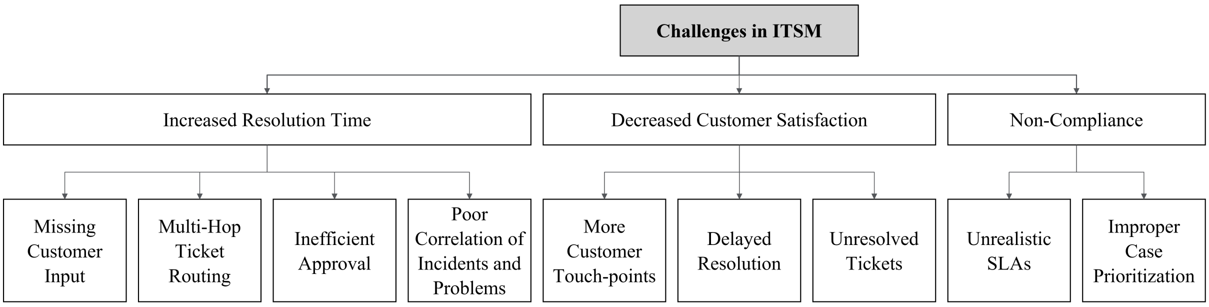

Figure 1.2: Typical Challenges in ITSM

1.2.3 Why ITSM Tool is not enough?

ITSM tool does not have any process mining analysis technique, and it lacks in exploiting the available process-related data [9]. Even when there is plenty of process-related data, organizations must learn how to handle incidents and requests. The data-driven solutions can eliminate the challenges and gaps in ITSM operations. Process mining delivers value that is tedious to obtain from typical ITSM solutions. Four significant aspects for understanding the value of process mining in ITSM include process visualization, process analysis capabilities, process expertise, and built-in process intelligence.

Aspect	ITSM Tool	Process Mining Tool
Process Visualization	Only primary Key Performance Indicators (KPIs) in standard charts. Lack of integrated way to visualize process variants	Comprehensive yet flexible and intuitive process visualization, inclusive of variant drill-downs. A full scope of KPIs and Process Performance Indicators (PPIs).
Process Analysis Capabilities	Process-related analyses are theoretically possible (in some tools) yet need to be configured manually. No direct connection between contextual information, process flow and performance metrics and, therefore, complex root-cause analysis within the process context.	Easy-to-use interface with interactive filter options. All contextual information is connected to the process and enables drill-downs to the root cause of the deviations.
Process Expertise	No core capability of process expertise - which is necessary to identify core process issues. Mostly only standard categories and grouping.	Extensive process expertise due to focus on process mining.
Built-in process intelligence	Integration of Artificial Intelligence is possible but usually requires custom implementation and does not provide process-specific insights. Comprehensive automation capabilities yet missing targeting.	Artificial Intelligence to check process conformance and proactively suggest possible root causes for deviations and ways to mitigate these.

Table 1.1: Comparison between typical ITSM solutions and process mining solutions

Firstly, ITSM platforms lack the way to visualize process variants and only provide basic KPIs in standard charts. In comparison, process mining provides comprehensive, flexible process visualization along with the feature of drilling down process variants. Such intuitive visualizations provide the full scope of PPIs and KPIs. PPIs provides fined-grained operational-level insights into any business process, and it complements KPIs by filling out missing details on the process perspective. Secondly, even though process-related analysis is theoretically possible, it requires configuring manually in ITSM tools. It is impossible to perform root cause analysis within a process context due to the lack of connection between contextual information, process flow, and performance metrics. Process mining tools through an efficient interface and interactive filter options connect contextual and corresponding processes and enable drill-down features to analyze root causes of the undesired process deviations.

Thirdly, ITSM tools lack the core capabilities of process expertise, which is crucial to identify the core issues in business processes. In contrast, process mining tools provide extensive process expertise as they work with process mining techniques. Lastly, ITSM tools can be integrated with artificial intelligence but need process-specific insights. Nevertheless, process mining tools and platforms use artificial intelligence to check process conformance and dynamically suggest possible root causes for deviations and insights to mitigate such bottlenecks. Table 1.1 summarizes the difference between typical ITSM tool and process mining, showcasing how process mining can bring value to ITSM process analysis and improvements. Hence, process mining is a powerful technology which can give businesses deep insights into the ITSM processes in a holistic view. Section 3.1.3 will introduce a detailed overview of the process mining discipline and its capabilities.

Deloitte Enterprise Service and Project Management

Deloitte is a leading global provider of consulting, risk advisory, financial advisory, tax, audit and assurance, and related services. The Enterprise Service and Process Management (ESPM) service line is the go-to partner for the most crucial, complex and disruptive technological challenges of client organizations in the Netherlands and worldwide. Within this service line, the ServiceNow team optimizes business outcomes by leveraging ServiceNow as an end-to-end digital workflow platform to enable seamless business operations. With the advent of process mining and its popularity over recent years, the ESPM team requires a guideline or a framework to apply process mining efficiently in the continual improvement of IT Service Management processes.

1.3 Research Objective

The primary motivation for this thesis was to guide the Deloitte ESPM business and the scientific community by filling the research gap of the combined application of process mining and continual service improvement. This research aimed to develop a generic process mining framework that guides the application of process mining technology to improve ITSM processes. ITIL framework provides a continual improvement model, and mostly the ITSM practitioners adopt it for continual service improvement practices. A qualitative interview with project, program and senior IT managers from eleven different industries across four countries revealed a positive relationship between characteristics of project success and project methodology [16]. The main objective is to fill the research gap between process mining and the ITIL Continual Improvement model. Thus, the process mining framework to be designed during this research must complement the service improvement practices supported by ITIL continual improvement model. The following sections introduce the research goals and requirements.

The research objective is segregated into smaller objectives as follows:

- **Sub-objective 1: Constructs of a process mining framework that is mappable to ITIL Continual Improvement model**
  Identifying activities in the application of process mining technology through a literature review
- **Sub-objective 2: Framework Refinement**
  Refining the framework by conducting interviews with domain experts to facilitate modification of the framework such that it fits the requirements and processes in reality.

- **Sub-objective 3: Framework Validation**
  Evaluating the framework through two methods, namely experts' opinion methods and case studies.

1.4 Research Scope

The scope of this research comprises designing a process mining framework for improving the ITSM service processes. It only addresses the guideline to leverage process mining techniques in the ITIL's Continual Service Improvement initiatives to assess and improve the ITSM service operations. It does not provide guidelines for actually implementing the service improvements. The designed artifact is a roadmap of when and how to leverage process mining techniques in continual service improvements. Therefore, the operationalization of the results is limited as metrics to quantify service improvements were excluded for scoping reasons.

1.5 Research Questions

Below research questions have been formulated for the critical analyses of process mining concepts in the context of improving the ITSM processes and creating the objective of this research. The main research question supports the research objective and is formulated as follows:

What constitutes a framework to assess and improve ITSM processes by leveraging process mining techniques in their ITIL continual improvement practice?

This central question gives structure to the goal of this research to improve ITSM operations by leveraging process mining techniques in the continual improvement initiative. The following sub-questions are addressed in this study to answer the main research question and guide this research. Table 1.2 provides an overview of the research questions introduced and corresponding details.

RQ1 **What are the process improvement methodologies for ITSM processes described in the literature?**
Throughout the literature, a variety of process improvement methodologies exist for ITSM processes. Therefore, this sub-question will serve to review relevant academic literature to identify the appropriate methodology for ITSM process improvements.

RQ2 **How can process mining be used for ITSM process analysis?**
The sub-question will serve to analyze the relevant literature meticulously to gather information on how process mining has been leveraged in the analysis of ITSM processes.

RQ3 **How can process mining be used to improve ITSM processes?**
The sub-question will serve to analyze the relevant literature meticulously to gather information on how process mining has been leveraged to improve the processes of ITSM.

RQ4 **What are existing process mining approaches adopted by ITSM practitioners?**
Since the research aims to bridge the gap between process mining and continual service improvements, this sub-question will serve to understand the scientific approaches adopted by ITSM practitioners to apply process mining in analyzing and improving service operations.

RQ5 **What are the prerequisites for applying process mining to ITSM process improve-**

ments?
This sub-question will serve to identify the prerequisites for successful process mining improvement projects, as the desired framework should provide components such as inputs and requirements for envisioning successful process improvements.

RQ6 **Which ITSM processes are suitable for improvements using process mining?**
This sub-question will help the researcher identify the service processes that can be suitable for process mining to be assessed and improved.

RQ7 **How can a framework be developed for the application of process mining to improve ITSM processes?**
To improve ITSM processes with process mining, the methodology should be integrated with a process improvement framework. This sub-question will serve to identify solutions for fulfilling the identified shortcoming. The answer to this sub-question will help synthesize the constructs of the framework to be designed.

RQ8 **How effective is the developed framework in practice?**
This sub-question will serve to validate the effectiveness of the developed framework in terms of satisfying the requirements. The framework's requirements will be introduced in Table 2.2.

Research Question	**Information Source**	**Chapter**	**Outcome**
1. What are the process improvement methodologies for ITSM processes described in the literature?	Literature Review	Section 3.4.1	Identification of ITSM improvement methodologies
2. How can process mining be used for ITSM process analysis?	Literature Review	Section 3.4.2	Knowledge on how process mining can be used for service process analytics
3. How can process mining be used to improve ITSM processes?	Literature Review	Section 3.4.3	Knowledge on how process mining can be used for service process improvements
4. What are existing process mining approaches adopted by ITSM practitioners?	Literature Review	Section 3.4.4	Identification of approach for applying process mining in ITSM sphere
5. What are the prerequisites for applying process mining to ITSM process improvements?	Literature Review	Section 3.4.5	Identification of key prerequisites necessary to apply process mining techniques for service improvements
6. Which ITSM processes are suitable for improvements using process mining?	Literature Review, Expert Interviews	Section 3.4.1, Chapter 5	Identification of process suitable for process mining application
7. How can a framework be developed for the application of process mining to improve ITSM processes?	Literature Review, Expert Interviews	Section 3.4.4, Chapters 4, and 5, 6	Empirical approach for designing the artifact, i.e. Process Mining for Continual Service Improvement (PM4CSI) framework
8. How effective is the developed framework in practice?	Expert Opinions, Case Study	Chapter 7	PM4CSI framework validation

Table 1.2: Overview of the research questions

1.6 Thesis Outline

The following chapters are structured as follows:

- Firstly, Chapter 2 introduces the design science research methodology adopted for this research and presents the stakeholders, goals, requirements, contribution and process of this design research.
- Chapter 3 describes the literature research conducted for this study and only presents the results obtained during the literature review.
- Chapter 4 describes information on designing and developing the initial version of the PM4CSI, PM4CSI V0.1.
- Chapter 5 provides the results obtained from the framework refinement expert interviews.
- Subsequently, Chapter 6 describes the refined version of PM4CSI during this study, i.e. PM4CSI V1.0.
- Chapter 7 describes the approaches adopted to validate the PM4CSI V1.0 and the results of the validation
- Lastly, Chapter 8 presents the discussion based on this research, and
- Chapter 9 provides the conclusion and prospects of this research project.

Besides additional results from this research, the appendix covers the complete overview of the process of research methods applied throughout this research.

Chapter 2

Design Science Research Methodology

As discussed in the previous chapter, this research aims to develop an artifact referred to as Process Mining for Continual Service Improvement, PM4CSI, a continual improvement framework by leveraging process mining techniques for improving the ITSM processes. Design Science Research Methodology (DSRM) is adopted to realize the PM4CSI artifact, which comprises of three parts: a high-level graphical abstract, a detailed overview of the framework and level-wise explanatory text in the form of an activity flow diagram and tables. Design science is the design and investigation of artifacts in the context of usage [13]. For this research, the Design Science Research Methodology proposed by Wieringa [13] was chosen as an appropriate research methodology. The rationale behind the choice is that it provides sufficient guidelines for doing design science in information systems and software engineering research. The methodology also elaborates on the famous DSRM by Peffers [17], which is considered an upgraded version and has an advantage.

The object of study is the artifact in a specific context, and the two major activities are designing and investigating this artifact in context to solve a design problem in that context. Within this research, the artifact is a process mining framework that guides ITSM process improvements, and the stakeholders are actors affected by the framework. The problem context is discussed in Section 1.2 of Chapter 1. Such an artifact that addresses the introduced problem context could have various designs, but the stakeholders' goals evaluate the usability. Hence, this chapter introduces the social context with the stakeholders, goals, and corresponding requirements. Then the research design template is adapted based on the research objectives, and the research demand is discussed. Finally, this chapter presents the research process adopted for this study.

2.1 Stakeholders and Goals

The stakeholders of a problem could be a person, team, or an institution affected by treating the problem. Since stakeholders are the source of the project's objectives and constraints, which are the source of the requirements, it is crucial to identify the appropriate stakeholders [18]. The domain of the framework is process mining and ITSM, specifically the application of process mining techniques in the context of improving ITSM operations.

Firstly, the main stakeholders are directly involved with the developed framework, i.e., process mining consultants and organizations that seek to improve their ITSM processes. The framework to be developed, PM4CSI, is for use by the process mining consultant and ITSM practitioner to improve the inefficiencies in the ITSM processes. In such a scenario, process mining consultants and/or ITSM practitioners are the intended users or *normal operators* (based on Alexander's taxonomy of stakeholders [18]), as they directly interact with the designed artifact. The organization that interact with these normal operators to apply the framework and benefit from the result are known as *functional beneficiaries*. Since normal operators and functional beneficiaries directly interact with the designed framework or appear in an intimate environment, its usefulness requires validation concerning their goals. Secondly, various other stakeholders

Stakeholder	**Alexander's Taxonomy [13]**	**Goals**
ITSM practitioners/ process mining consultant	Normal operators	Leverage the developed framework to apply process mining techniques in continual service improvements
Organizations seeking improvements in ITSM operations	Functional beneficiaries	Improve ITSM operations through application of process mining capabilities
Subject Matter Experts (SMEs)	Consultants	Transfer knowledge of the domain and/or practical implications
University of Twente	Knowledge Supplier	Contribute to scientific community and practice
Deloitte ESPM	Sponsor	Develop tools and capabilities to assist clients in effectively managing and reaping the benefits of data assets
Author	Researcher, Developer	Research and develop a framework that fulfills the requirements and objective of the main stakeholders

Table 2.1: List of possible stakeholders of PM4CSI framework, based on Alexander's Taxonomy

are involved in the development of the framework. The University of Twente is the *Supplier* of knowledge. The SMEs who participated in the interviews served as *Consultants* and supported the development of the framework. Deloitte ESPM is the *Sponsor* of this research. The author is the researcher and developer of the PM4CSI framework. In short, Table 2.1 sums up the stakeholders involved, their classification, and their goals.

A framework is a blueprint or guides for conducting an activity developed based on an existing theory in a field of inquiry that is related to and/or reflects the hypothesis of a study The framework developed during this research aims to provide a guideline for applying process mining in analyzing the processes in ITSM operations to improve efficiency, increase customer satisfaction, reduce resolution time, and ensure compliance.

2.2 Requirements

Requirements have been established to fulfil the research gap and provide a framework to help ITSM practitioners go through the ITIL Continual Improvement Model steps more effectively by leveraging process mining techniques. Table 2.1 describes the desires of each stakeholder and their goals for the framework. The requirements establish the envisioned properties of the designed framework. In other words, requirements are the goals for the to-be-designed PM4CSI framework. Thus, requirements are crucial to achieving the stakeholders' goals, and these requirements form the basis of the evaluation of the designed framework. The activities taken within each step in PM4CSI are explained to guide and support ITSM practitioners through the improvement project. Thereby, the following functional requirements are specified

- Alignment of Continual Improvement and Process Mining - The necessary steps and requirements for leveraging the process mining technology to improve ITSM processes continually must be specified

- Guidelines - The activities within each step of the PM4CSI to be thoroughly explained.

The guideline flow should be focused on a process mining approach designed for continual service improvements to use the process mining tool and techniques effectively in each step. The requirements shown in Table 2.2 serve as goals for framework design during the development phase, and these are the criteria during the evaluation phase.

Property	Possible indicator
Relevance	The steps in the designed framework are relevant to the domain
Comprehensiveness	The steps cover all the tasks involved/impacting in the domain
Utility (Usefulness)	The framework is useful for applying process mining technology to improve ITSM processes
Usability (Ease of use)	The steps, documentation, and guidelines should be easy to apply in practice
Tool Independent	Framework to be practical and hence focus is best kept on business-oriented tools such as Celonis, Process Advisor, and so on.

Table 2.2: Evaluation criteria for framework to be design

2.3 Design Problem

In addition to the objectives mentioned in section 1.3, the goals of this research are applied to the design template proposed in the DSRM by Wieringa [13]. For successful implementation of the methodology, it is essential to identify the research problem context, the artifact designed to improve the problem, the requirements of the artifact, and stakeholder goals.

The following design problem template by Wieringa will suit this process.

improve <a problem context>
by <(re)design an artifact>
that satisfies <some requirements>
in order to <help stakeholders achieve some goal>

When applied to this research context, the design problem template produced is as follows:

improve *ITSM operations*
by *designing a process mining framework*
that *guides the application of digital process mining techniques*
in order to *reduce resolution time and increase customer satisfaction, thereby improving the efficiency of ITSM processes, in turn gaining competitive advantage.*

2.4 Contribution Argument

Generally, the requirements specification is a vital design activity of the design researcher, and it is essential to provide a contribution argument to justify the choice of requirements. A contribution argument is simply an argument that an artifact when interacting with a problem context, satisfies specific requirements that would contribute to the goals of involved stakeholders [18]. The contribution argument of this research is as follows:

- If the developed process mining for continual service improvement framework satisfies the requirements that it can guide the ITSM practitioners in the application of process mining,

- and assuming that process mining technology is integrated into the process analysis of ITSM process improvements,
- then the designed framework contributes to
  Deloitte's goal - have an out-of-the-box guideline for leveraging process mining techniques in their work with continual service improvements.
  scientific community - by bridging a gap between ITIL Continual Improvement Model and Process Mining, and thereby contributing a framework that acts as a guideline for applying process mining techniques to perform continual service improvements efficiently

2.5 Relevance and Demand

Organizations facilitate the automation of their ITSM processes and use cutting-edge technologies for prompt delivery and maintenance of services reliably and cost-effectively [12]. Interviews with the SMEs during this research will confirm relevance and demand in practice. The interviews (refer sections 5.2, 5.3 and 7.2.4) were additionally used to refine and evaluate the framework. Experts interviewed during this research provided information on whether a process mining framework for ITSM process improvements would be of help and relevance. All the participants indicated high relevance and demand for the designed framework with a positive sentiment. The designed framework expects to serve as guidance for when and how to leverage process mining techniques in ITIL's Continual Improvement initiative and serve as a guideline to create a roadmap for improving ITSM processes efficiently.

2.6 Research Methods

The following methods are used in this research.

- Literature review - method of identifying, validating, and synthesizing the existing scientific work published by scholars, researchers, and practitioners [19].
- Interview - Qualitative research technique involving the exercise of asking questions with experts to collect data from the field of the research.
- Expert opinions - Experimental study of the artifact by experts' mental simulation.
- Case study - research of a single case to explore the effects of the underlying concepts of the research artifact.
- Survey - data collection method using written responses and rating to questions and statements.
- Grounded theory data analysis - a method for adding additional concepts to the conceptual framework found in the interpretative data analysis.

2.7 Research Process

The answers to research questions mentioned in the section 1.5 will lead to the refinement of the process mining framework for the application of process mining techniques in ITSM process assessments and improvements. For this research, the Design Science Research Methodology proposes structured processes from problem investigation to the design and validation of an artifact [13]. Figure 2.1 presents the entire engineering cycle by Wieringa, and the scope of this research excludes the Treatment Implementation and Implementation Evaluation steps. Excluding these two steps, Wieringa's engineering cycle could be referred to as the design cycle [13].

The design cycle consists of three phases for developing information systems artifacts: problem investigation, treatment Design and treatment validation. In the first phase: Problem investigation, it is essential to investigate an improvement problem to motivate the design of the artifact [13]. All requirements for the artifact will be identified later and followed by the second phase: Treatment design, where the actual process of designing the research artifact occurs. Lastly, the third phase, treatment validation, is when the artefact is validated to prove that the artifact can achieve the goals set prior. Figure 2.2 illustrates this research process. The applied research methods will be briefly discussed in the chapters corresponding to each process step. The research problem will be investigated by following experts interview, a systematic

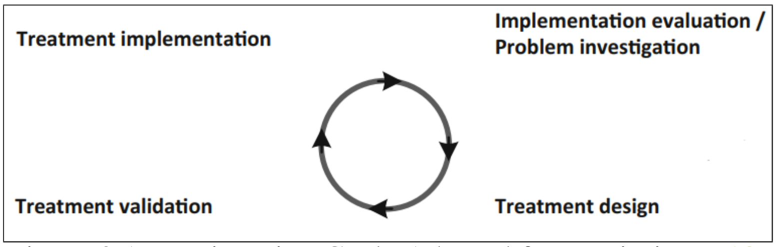

Figure 2.1: Engineering Cycle Adapted from Wieringa [13]

literature review (SLR), and a semi-systematic literature review (SSLR). Nevertheless, before the mentioned investigation approaches, the research topic report submitted to the University of Twente served as a scoping search [20] to familiarise with the field of process mining first and obtain a more detailed research direction. Interviews were conducted with ITSM practitioners to understand the challenges in the domain to formulate the problem statement of this research as described in Section 1.2. The SLR served to clarify the state-of-the-art knowledge of how process mining has been used in the IT Service Management sphere and identify the existing process mining methodologies, and answer related research questions (RQ1 to RQ6). From the SLR, when it became apparent that most published papers did not follow any specific or comprehensive process mining methodology in the field of process mining for ITSM process improvements research, an SSLR was executed to support the semi-structured identification of generic process mining methodologies or frameworks.

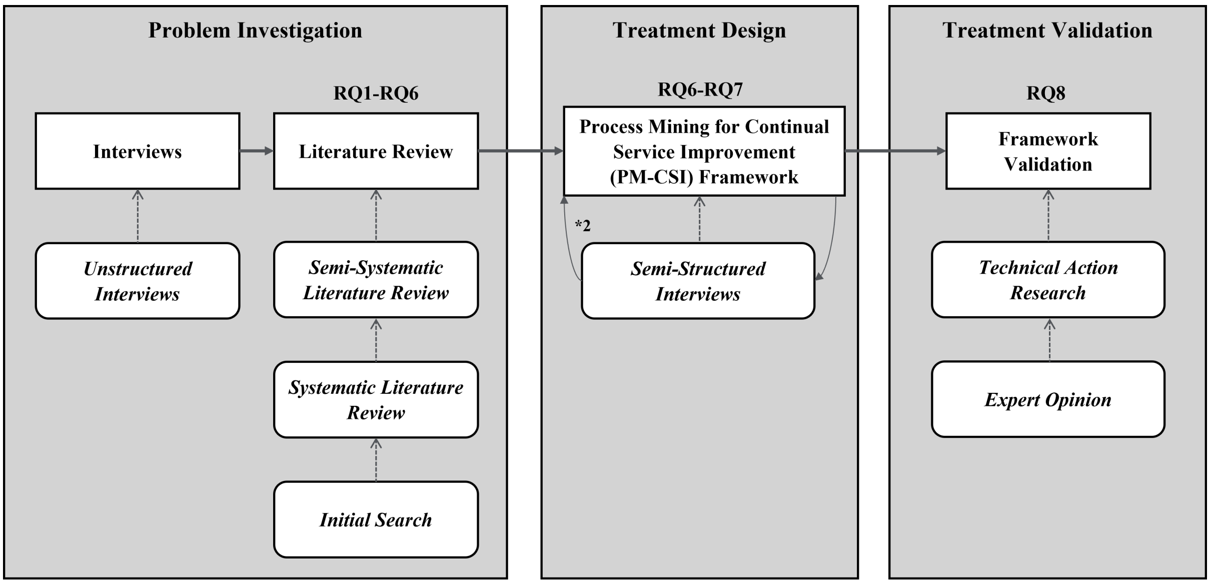

Figure 2.2: Research process adopted during this research project

Considering that only limited academic literature discussed the approaches adopted for applying process mining to continually improve ITSM operations, interviews with SMEs from the field of process mining were planned to acquire information on the tasks and requirements identified throughout the SLR and SSLR. These interviews will help identify relevant tasks carried out during process mining projects and help align such tasks to the ITIL Continual Improvement Model. The expert panel should be chosen to obtain insights from experience with various process mining tools. Through the semi-structured expert interviews, feedback on the initial and intermediate versions of PM4CSI can be obtained, which will be used to adapt the initial design of the framework.

The adapted and refined version of the PM4CSI will be demonstrated to experts in Process Mining and/or ITIL. The designed framework will be validated through expert opinions and case studies. The framework should be demonstrated during the expert opinion interviews. To evaluate the usability and utility of the PM4CSI, i.e., usefulness and easy-to-use by the practitioners, with a survey formulated on the constructs of the Technology Acceptance Model 2 [21]. The expert interviews for framework refinement were conducted during the design and construction of PM4CSI. Hence, the expert interviews for framework refinement are *ex-ante evaluations*, i.e. the experts interviewed were involved in the assessment of an artifact to expose its potential [22]. The validation interviews and the surveys were implemented after the framework was developed, and they were *ex-post evaluations* [22]. Case studies include using the designed experimental artifact, PM4CSI, to help a client, which will allow the researcher to learn about PM4CSI effects in practice. The case studies will also verify if the designed framework satisfies the requirements, viz. relevance, comprehensiveness and tool independency.

2.8 Summary

- Wieringa's Design Science Research Methodology has been adopted to realize the framework to be designed (PM4CSI), which will comprise of three parts including a high-level graphical abstract, a detailed overview of the framework and level-wise explanatory text in the form of an activity flow diagram and tables.
- The framework to be developed, PM4CSI, is for use by the process mining consultant and ITSM practitioner to improve the inefficiencies in the ITSM processes. Other stakeholders of this research can be found in Table 2.1.
- Requirements of the framework to be designed have been established corresponding to the desires of each stakeholder's goals. The process mining approach should be aligned with the continual improvement steps and comprehensive guidelines of the activities taken within each step. The non-functional properties, which also serve as criteria to evaluate the framework, have been established in Table 2.2.
- Additionally, Wieringa's design problem template and contribution argument have been formulated to provide guidance and justification for the choice of requirements in section 2.3 and 2.4, respectively.
- Different types of empirical methods have been used in the research to conduct scientific research and address validity and generalizability issues. The research process follows the design cycle of Wieringa by conducting problem investigation, treatment design and treatment validation as illustrated in Figure 2.2.
- The next chapter provides the process and results of the literature review conducted during this research to understand the state-of-the-art of the applying process mining techniques in the ITSM process improvements. The output of the literature review will be used in developing the process mining framework for continual service improvements.

Chapter 3

Theoretical Knowledge

This chapter is dedicated to providing a theoretical background that has been gathered to understand the domains of the research context individually, followed by a literature review to grasp the state-of-the-art in the application of process mining techniques in ITSM sphere.

3.1 Background

This section of the report presents conceptual knowledge on the fields of the research interest: ITSM and process mining, to provide a deeper understanding of both disciplines. Section 3.1.2 presents data gathered through scoping research on ITSM. Two associates from the Deloitte Enterprise Service and Process Management (ESPM) team, having extensive experience in the domain and possess ITIL certifications, transferred knowledge which aided the basic understanding of ITIL and ITSM. The following sections 3.1.1 and 3.1.3 describe process mining concepts, capabilities, and perspectives for which the data gathered was by a systematic literature review conducted during the author's research topic coursework. Data gathered by analyzing Deloitte's internal documents do not appear in the bibliography of this report due to confidentiality.

3.1.1 Business Process Management

Firstly, it is important to understand Business Process Management (BPM) lifecycle to describe process mining [11]. BPM evolved as a discipline that combines knowledge from both information technology and management sciences [23] and applies such knowledge to business process operations. Organizations and practitioners have widely adopted BPM technologies to model, optimize, and enact business processes [24]. The business process lifecycle consists of different phases in a cyclically organized structure, along with the logical description of their inter-dependencies [25], as seen in Figure 3.1. It emphasizes the various phases of managing a specific business process. Generally, a business process includes the following phases: *(re)design, configuration, enactment, and evaluation*.

During the *design* phase, the designing of the process takes place. Following this, the designed model is implemented into a running system in the *configuration* phase. Once the system can support the designed processes, monitoring of the processes starts in the enactment phase. If any changes are required, the processes are reconfigured. In this phase, the processes are not redesigned, or there is no new process enabling. The processes are evaluated in the *evaluation* phase, and the emergence of new requirements due to changes in the process environment, such as changing policies, legislation, and many more, is monitored. A new iteration leads to

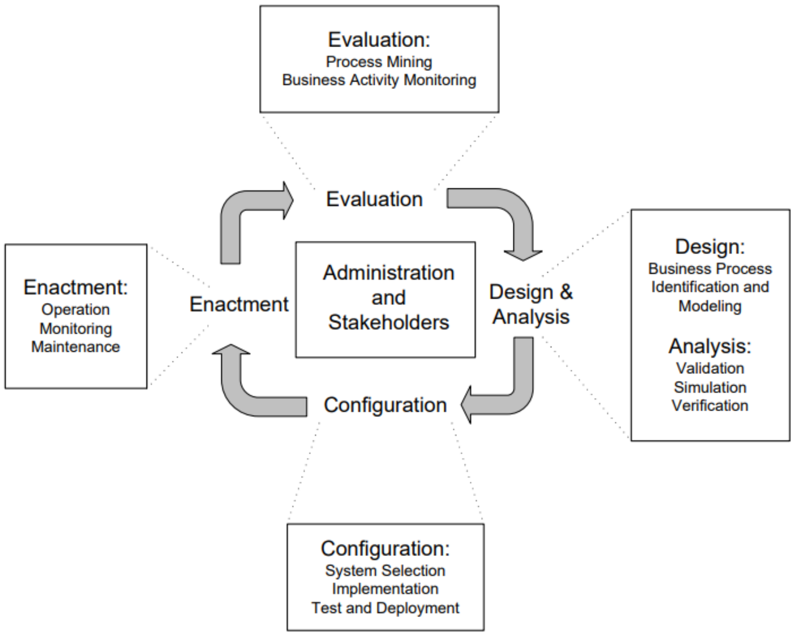

Figure 3.1: Life-cycle of a business process [25]

redesign phase, which is triggered based on the need for performance improvement or due to changes in the process environment [11].

Improving business processes and maintaining performance levels are the crucial success factors of any organization. The key benefits of implementing BPM for IT services include educating the IT department about business goals connected to business development. Consequently, BPM offers a comprehensive approach to implementing repeatable processes and the subsequent automation and continuous development of these processes, whereas ITIL is the methodology of governance, control, and service outputs.

Business Process Improvements (BPI) requires an in-depth understanding of As-Is processes and problems that hinder their optimal performance. Traditionally, these processes' value or process mapping methods and detection of potential improvement areas relied on manually derived estimates based on interviews and workshops with employees involved in the process [26]. These manual practices are expensive in terms of time and cost and can unintentionally reflect the prejudices and misconceptions of those who created them. In the best case, the data from these assumptions would be incomplete, and in the worst case, it would be inaccurate. Process mapping is subjective, lengthy, costly, and a one-time solution.

3.1.2 Information Technology Service Management

During the initial days of computer usage, human resources relied on the IT department for assistance in the event of an issue. Over the period, as businesses expanded the IT infrastructure, formalized help desk or service desk model came into practice. Setting up IT service management processes enables organizations to improve the quality of service and ensure greater compliance by standardized processes. ITSM is a part of Service Science. ITSM refers to "the entirety of activities, directed by policies, organized, and structured in processes and supporting procedures, that are performed by an organization to design, plan, deliver, operate, and control IT services offered to customers" [27, 28]. ITIL v4 defines *service management* as *"a set of specialized organizational capabilities for enabling value for customers in the form of* *services"* [2]. Such capabilities require understanding the nature and scope of stakeholders, value, and how services enable value creation. Therefore, ITSM includes people, technology, and processes that are used to implement, deliver, manage and support IT services.

ITSM focuses on IT operations such as delivery and support of services. In simple words, ITSM is how IT department manages the end-to-end delivery of IT services to end-users. Consider a web content management service offered by a service provider for managing a website for exhibitors conducting exhibitions worldwide. Ticket management systems support the customers in handling the issues raised during the project maintenance. For example, if a website experience downtime, the end-users satisfaction will be impacted. To fix such an issue, the customer reaches out to the support team in charge by raising a ticket in a service management platform, say ServiceNow. What happens after creating the service ticket in the ServiceNow platform does not concern the customer. ITIL provides best practices and guidance to implement, manage, and deliver IT as a service. An incident is an event that can cause disruption of services and lead to loss [6]. *Website downtime* is an incident that requires a fix for the disruption at the earliest. In such a scenario, the ticket management information system assigns an incident to the relevant support team. The support team aims to resolve the incident by fixing or performing a workaround for the reported issue. During this process, the incident goes through different activities such as ticket assigned, ticket opened, work in progress, awaiting customer input, supplier escalation, completed, and resolved. These activities are considered the lifecycle of the said incident management process, which varies based on different contexts and organizations.

Figure 3.2: ITSM framework by Berkeley University

ITSM has been in the focus for the past two decades in many industries, providing a framework that assists in structuring the IT operations to deliver high-quality and efficient IT services which are required to meet the business requirements and comply with SLA [29]. Business processes are at the core of ITSM. Being a process-oriented discipline, ITSM shares common concepts with process improvement methodologies such as Total Quality Management (TQM), Six Sigma, Lean, BPM, and Capability Maturity Model Integration (CMMI) [1]. It emerged as a discipline that aims to optimize IT services to satisfy business-level requirements while better orienting IT with organizational objectives. In 2011, an international survey of 491 enterprises revealed that over 90% of the companies use ITSM frameworks in some way to enable their IT operations [30]. With the accelerating pace of the digital transformation revolution, ITSM is undoubtedly the needed business model that can hold digitalization efforts to a scalable and sustainable level. Figure 3.2 illustrates the ITSM management framework designed by the Berkeley University of California.

ITSM focuses on a set of well-defined and well-established processes that conforms to standards such as ISO/IEC 20000-1 and best practices such as ITIL. ITIL is a framework that provides detailed best practices for IT activities, and it facilitates the high-quality delivery of IT services at a reasonable cost. To effectively manage IT services, several guiding principles have been provided by standards like ISO/IEC 20000-1 [31], ISO/IEC 15504 [29], ITIL and Capability Maturity Model Integrated for Services (CMMI-SVC) [32]. A survey with responses from global-level senior executives revealed that ITIL had been ranked as the most popular framework [5]. Thus for many such reasons, ITIL has been considered the de facto industry standard of reference model accepted for ITSM. ITIL is adopted globally [4], even though there are different standards and frameworks available to contribute to the ITSM discipline. Table A.1 from Appendix A shows the service management practices based on the ITIL V4 framework [2]. ITSM improves efficiency to IT processes through these practices.

IT is becoming a crucial business driver after the bloom of developments such as Infrastructure as a Service (IaaS), artificial intelligence, blockchain, and cloud computing that have opened opportunities for the creation of value and competitive advantage. IaaS makes ITSM an essential strategic capability. In practice, ITSM is crucial for every business for various reasons, such as to promote business and IT convergence, drive IT efficiency, increase consumer satisfaction, support constantly changing regulatory compliance, and reduce the lifecycle of the incidents.

3.1.3 Introduction to Process Mining

Even well-documented and controlled processes generally do not behave as desired and must be verified objectively to improve. Transparency is a prerequisite for digital transformation [33]. Traditional approaches fail to absorb the real-life complexity of business processes. It is difficult to extract insights from the increasing volume of data available nowadays, and such data have a better idea of process optimization than human assumptions. A data-driven approach is needed to have a more objective and holistic approach to understanding the processes. With the advent of Information Systems and administrative tools such as Process Aware Information System (PAIS), businesses use algorithms and vast amounts of dynamic real-time data to create business value. Enterprise Resource Planning systems, Business Process Management systems, Customer Relationship Management systems, Workflow Management Systems, and call centre software [11] can be viewed as process-aware systems. The data from these systems can be a vital source for analyzing the process. Gartner defines process mining as "software that visualizes actual processes based on event data available in information systems, providing fact-based visibility to spot bottlenecks and avoidable delays occurring due to manual inefficiencies."

Process mining provides a transparent, comprehensive perspective of all activities occurring within a company, rather than concentrating solely on process management, and enables a more profound analysis of those activities. Process mining combines formal model-based process analysis and data-centric analysis methods. *Wikipedia* defines process mining as "a process management technique that allows for the analysis of business processes based on event logs". It is objective, faster, and continuously monitors and enhances the process [33].

Process mining essentially uses Data Science techniques, such as big data, statistics, and artificial intelligence, to address Process Science problems such as process improvement, operations management, and automation. Aalst [11] depicted the link between process science and data science as shown in Figure 3.3. In contrast to traditional data mining, process mining places more of an emphasis on concurrent processes than static or mostly sequential structures [34]. Process mining brings life to static process models and contextualizes massive amounts of data stored in the PAIS. Process mining aims to extract helpful process knowledge by exploiting transactional data from these information systems [35]. Process mining may answer a wide range of compliance and performance questions, both data-driven and process-centric, using a combination of event data and process models.

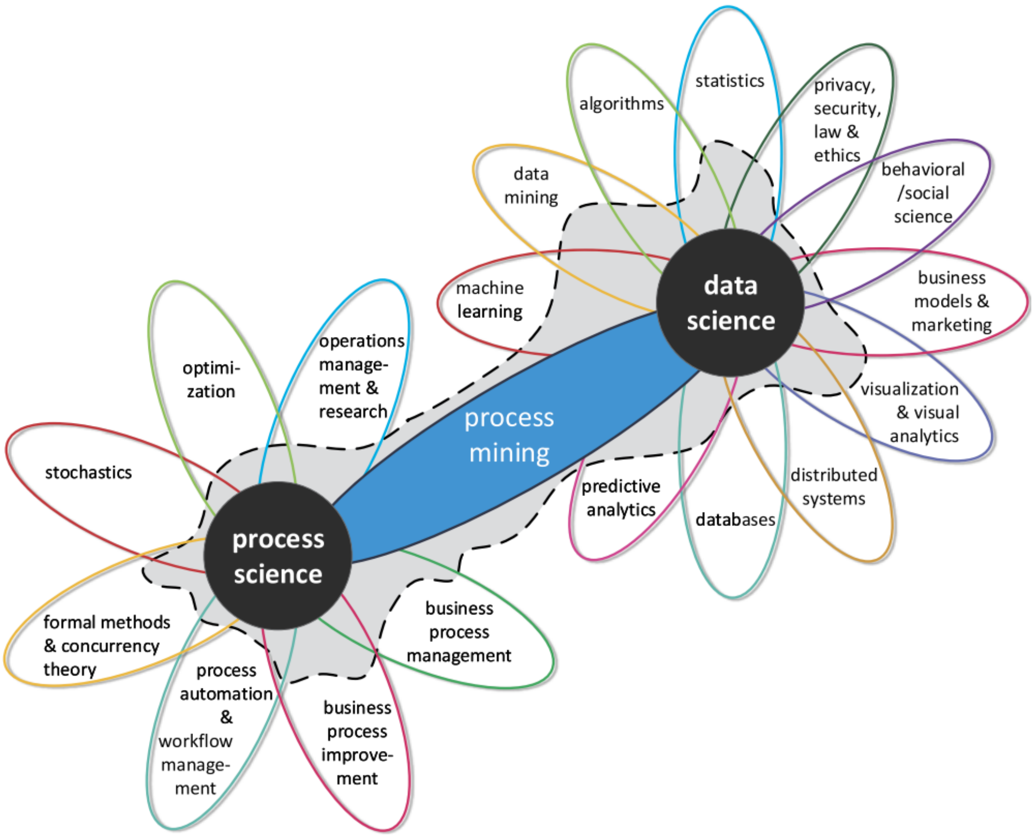

Figure 3.3: Process Mining as a bridge between process science and data science [11]

The Enterprise Service Management platforms, such as ServiceNow or SAP, capture audit logs in various information systems. Any process interactions generate data that will be stored in PAIS like Workflow Management Systems (WfMS), Enterprise Resource Planning (ERP)) (e.g. SAP), Supply Chain Management (SCM) (e.g. Manhattan Associates), and Customer Relationship Management (CRM) (e.g. Salesforce) [36, 24, 37]. PAIS stores these event logs to record the events taking place for each business transaction ID and its timestamp. Process mining aims to produce insights and recommendations from low-level event data. Typically, event logs contain more information in addition to the timestamps and activity names, such as an identifier of resources(e.g. machines, humans) executing an activity, input data(e.g. customer age, bill amount) required to execute an activity, output data created by executing an activity(e.g. recommendations, outcomes), and information on how multiple events correlate (e.g. lifecycle of an activity) [38]. The prevalence of event logs is a critical enabler of process mining, i.e., running-time behaviour analysis is possible only by recording the events.

Process mining can model as-is processes based on event log data from companies' information systems. It eliminates manual process mapping, which is prone to manual error and time consumption by relying on verifiable data from IT systems [11]. Process mining technology uses these disciplines (refer to Figure 3.3) by analyzing the digital footprints extracted from the related PAIS to automatically visualize and reconstruct the actual process flow, allowing the technology to identify patterns from natural processes and deviations from ideal process flows and eventually eliminate bottlenecks. Companies can optimize, innovate, and help accelerate their products and services and fundamental business operations with the help of these enormous amounts of digital footprints. Process mining helps in discovering the As-Is phase of a business process in its full complexity, measuring its conformance with a desired ideal model, finding anomalies, and bottlenecks, tracking policy violations patterns or variants, and improvement areas, thereby enhancing and streamlining the process and making it almost similar to the ideal process model [11]. Process mining is a technology that acts as an enabler for Business Process Intelligence, Corporate Performance Management (CPM), Six Sigma, TQM, and other process improvement methodologies [39].

Figure 3.4 shows the central role of process mining in the BPI lifecycle [11]. Throughout the whole BPI lifecycle, process mining is utilized as a fast, accurate method to repeat the process analysis to maintain and monitor process change. By leveraging the data tracked by different PAIS, representing truth and reality with no subjectivity, process mining enforces certainty in the early phases of BPI.

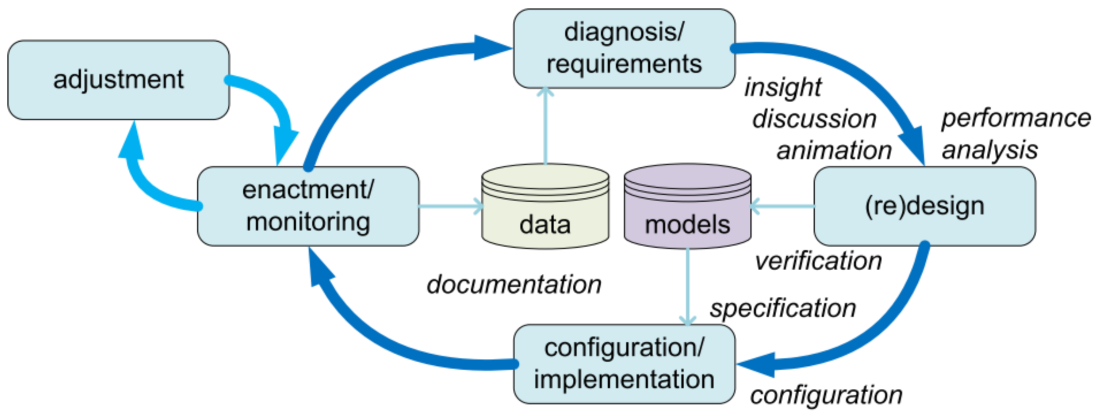

Figure 3.4: Usage of process models across business process life-cycle [11]

Process mining elements depend on various dimensions such as systems(single or multiple), single or cross-organization and the nature of the service or product(physical or digital) supported by the real world. Cross-system or cross-boundary process mining has a lot of potentials because it is crucial to get an end-to-end view of processes [40]. Figure 3.5 shows the conceptual mapping of process mining based on the entities from Figure 3.7.

3.1.4 Event Logs

Firstly, gathering all the information required for a process reconstruction is important for every process analysis. The starting point of process mining is IT based work regardless of the process or workflow. Any process interactions generate data that will be stored in PAIS like WfMS, ERP) (e.g. SAP), SCM (e.g. Manhattan Associates), and CRM (e.g. Salesforce) [36, 24, 37]. The data from these systems contain three pieces of information along with other data attributes [11]: *Process steps or activities* that have been conducted; *Points and time* at which the activity

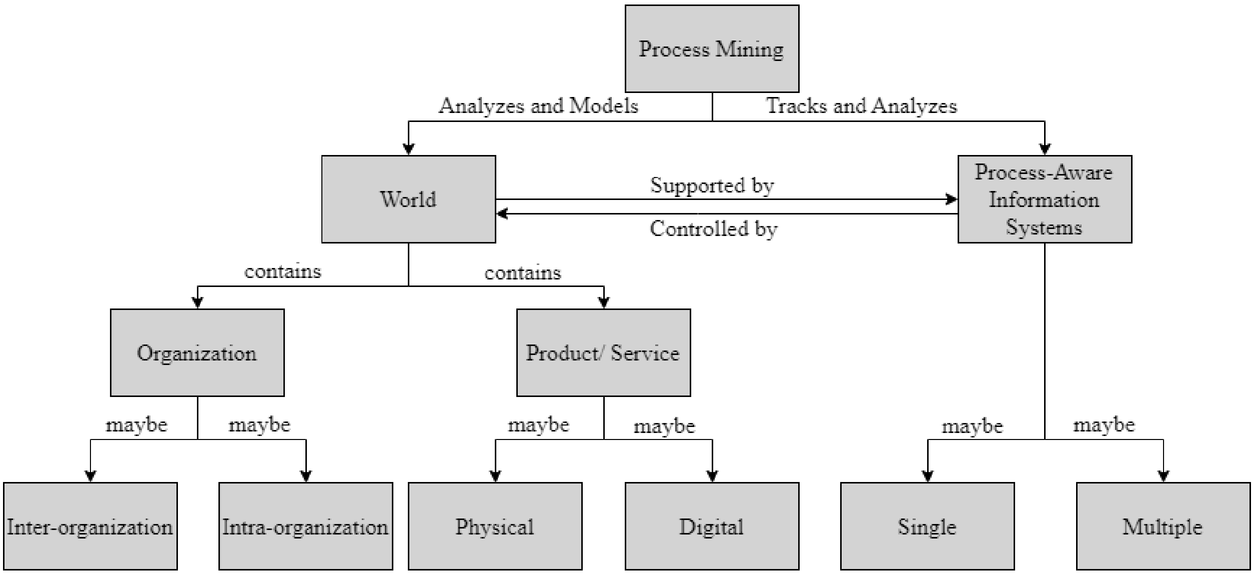

Figure 3.5: Process Mining Conceptual Model

was carried out; *Object or ID* for which the activity has been executed. A combination of these three is called a digital footprint [33]. For example, consider an Order2Cash process – a business process for receiving and processing customer orders for goods and services and their payments. In a globally operating online retail process, the information systems record data when an order has been received, goods have been shipped, or invoice creation. These data have information about what has been done, when it has been done, and for which sales order it corresponds. Such a digital footprint will include at least the following pieces of information:

1. *Case ID*: a unique identifier such as a purchase order item, invoice number, or order number.
2. *An activity*: the description of what has happened - for example, the creation of a purchase order or the receipt of goods.
3. *A timestamp*: the date and time that the activity took place

The digital footprints form the basis for building digital twins of the business processes. Such digital footprints can be retrieved from underlying IT systems as *Event Logs*. PAIS stores such event logs to record the events taking place for each business transaction ID and its timestamp. Process mining aims to produce insights and recommendations from low-level event data. Typically, event logs contain more information in addition to the timestamps and activity names [38], such as an identifier of resources(e.g. machines, humans) executing an activity, input data (e.g. customer age, bill amount) required to execute an activity, output data (e.g. recommendations, outcomes) created by executing an activity, information on how multiple events correlate (e.g. lifecycle of an activity).

Process mining technology uses digital footprints to visualize and automatically reconstruct the actual process flow. Consequently, event data can be utilized meaningfully, for instance, to provide insights, detect bottlenecks, foresee issues, track policy violations, suggest solutions, and streamline processes. Besides the data from the PAIS, event data can also be retrieved from numerous situations and contexts- Automated payment or Internet of Things(IoT) in production and other industries [41]. The prevalence of event logs is a critical enabler of process mining, i.e., run-time behavior analysis is possible only by recording the events.

3.1.5 Process Mining Capabilities

There are three main capabilities of process mining [11] as shown in Figure 3.7 namely,

- ***Discovery***: Describes direct insights into the as-is process. Unlike traditional process management: techniques, process mining provides objective, data-based insights into the as-is process in its full complexity. The input for this type of process mining is Event Log, and the expected output is a process model [39].
- ***Conformance checking***: Refers to comparing the as-is process to the desired model. Conformance describes how far and in how many scenarios the as-is process deviates from the ideal model. Furthermore, discovery can help reconstruct a realistic model that captures the actual complexity behind the process. The inputs for this type of process mining are Event Logs and process models, and the expected output is diagnostics [39].
- ***Enhancement***: Refers to all actions and measures of improvements taken to bring the as-is process closer to the desired model. It encompasses any feedback from the real world, including predictions and recommendations. As a research field, Enhancement opens up an entirely new world for the adaptation and use of process mining within organizations and how it helps create actual business value and insights. The inputs for this type of process mining are Event Logs and process models, and the expected output is a new process model [39].

In the beginning, the efforts in the process mining domain focused on process discovery [11]. However, there has been an improvement in the clarity that process discovery is only the starting mark to process improvements. Also, over the past two decades, the process mining scope expanded in various ways. Due to the recent advances in artificial intelligence and machine learning, process analysis capabilities extends into areas such as predictive analysis, prescriptive analysis, scenario testing, and simulation [42, 43]. The focus is now shifting from backward-looking to forward-looking [33]. Figure 3.6 shows the different process mining techniques for managing and improving business processes.

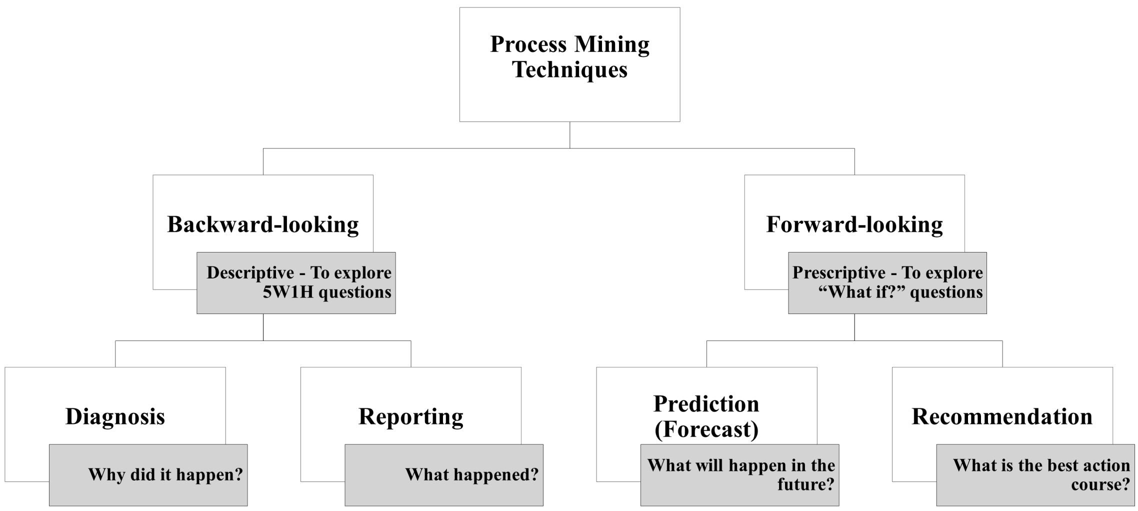

Figure 3.6: Process Mining Techniques

Traditional process mining techniques use historical data to diagnose issues with compliance and conformance. Companies are inquisitive about what is happening and what will happen next. With backward-looking process mining, minimal support for daily process management can improve processes. Thus, there is a requirement to update event data continuously and process mining techniques to perform run-time analysis of processes. Forward-looking process mining allows predicting what will happen to individual instances and where deviations are likely to develop. It is categorized into prediction models using: *(i) Simulation techniques* and *(ii) Machine Learning techniques*, such as [10]. Figure 3.7 shows the position of process mining capabilities for forward-looking and backward-looking process mining techniques.

Besides the three main types of process mining mentioned in this section, studies by [44] and [45] show other features of process mining activities such as

- ***Process variant analysis***: Discovery of different process variants (frequencies, traces, and performance measures) and identification of the most prevalent ones.
- ***Process exploration***: Evaluation of discovered process model and further exploration of a satisfying model.
- ***Decision point analysis***: Extension of an existing model with data-related attributes (e.g. age, gender, product category)
- ***Organizational analysis***: Establishing a social network, identifying relationships between organizations or roles, or extending an existing model to include resource characteristics.
- ***Performance analysis***: Process performance analysis aiding the identification and quantification of bottlenecks.
- ***Performance target analysis***: Identification of problematic cases by filtering them according to the baseline or target value.
- ***Predictive monitoring***: Prediction of violations or recommendation of best practices based on execution or simulation.
- ***Outlier detection***: Detecting the occurrence abnormal values in event logs.

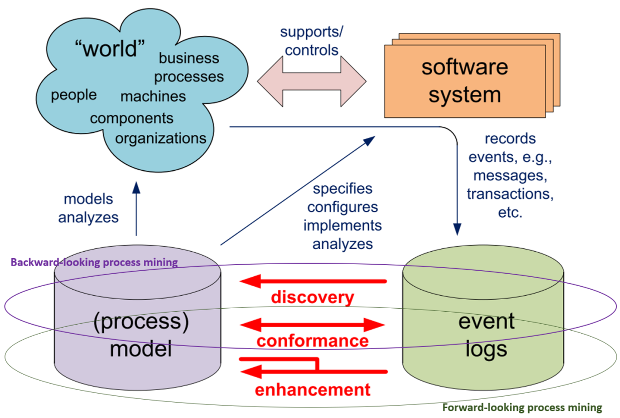

Figure 3.7: Positioning the process mining capabilities: *Discovery, Conformance, and Enhancement* [11], and process mining techniques: Forward-looking and Backward-looking process mining

3.1.6 Process Mining Perspectives

The process mining capabilities mentioned in Section 3.1.5 are supported by various perspectives of process mining [11] based on the characterization of the behavior of the Event Logs. Characterization such as frequency of an activity occurrence or throughput time provides in-depth information on differential behavior between different process variants [46]. Other perspectives, such as the organizational perspective ("Who?") and the case/data perspective ("What?"), may be examined in addition to the control-flow perspective ("How?") [11]. However, many of these additional perspectives are built upon the identified control-flow model and greatly depend on identifying a control-flow model of sufficient calibre. However, even if the control-flow model's quality is excellent, these additional perspectives still face difficulties [47].

A systematic literature review on process mining perspectives in Software Engineering [48] revealed the identification of four significant process mining perspectives viz. (i) *Control-flow (or process)* perspective, (ii) *Time* (or Performance) perspective, (iii) *Case* perspective, and (iv) *Organizational* perspective. The findings highlighted the use of the control-flow perspective in discovering process models and the organizational perspective in identifying human resource interaction. Another study [38] provided a five-perspective view on processes viz. (i) *Control-flow (or Behavior/Behavioral)* perspective, (ii) *Resource (or Organizational)* perspective, (iii) *Data (or Case/Object/Information/Informational)* perspective, and (iv) *Time* perspective, and (v) *Function* perspective. The process extension capability intends to incorporate the process perspectives on data (or decisions), organizational (or resources), and time into the business process model. Such a practice allows designers to fine-tune the model requirements, resulting in more precise models [49].

Therefore, the significant process mining perspectives identified in the literature are:

- ***Control-flow/ Process*** perspective focuses on the identification of activities and their sequence, which allows us to find a good characterization of all possible paths [11].
- ***Organizational/ Resource*** perspective is concerned with the actors(e.g., systems, departments, people, roles) who are in charge of executing tasks inside the process [50], and how they are related. The purpose is to structure the organization by categorization the people into roles and organizational units or to display the social network [11].
- ***Time*** perspective is concerned with quantitative temporal circumstances such as when tasks can/must be scheduled and executed, as well as their expected duration[50]. It is concerned with the timing and frequency of events that contain timestamp data [49]. When events have timestamps, it is possible to identify bottlenecks, assess service levels, monitor resource usage, and predict the remaining processing time of ongoing cases [11].
- ***Data/ Case*** perspective records how data items and their attributes impact and are altered during the execution of the process [50]. A case may be characterized by its progression through the process, the originators working on it, or the values of the respective data components. For example, if a case represents an order payment, the due date or the total amount may be of interest [11].
- ***Function*** perspective focuses on the activities that are part of the process. Mostly, the activities of a process are not at the same level of abstraction. The execution of multiple activities at the low level of abstraction combines to form an activity at a higher level. With a functional perspective, it is best to leverage the domain knowledge of the underlying relationship between low-level events and high-level business activities to improve discovered business process model [38].

The control-flow perspective, as expected, is applied in almost every work as it is the basis for further analysis of the process. It is interesting to note that these perspectives can be interlinked based on their correlation to provide impactful business decisions [11]. While the control flow is the primary process backbone, other equally significant perspectives, for example, time, costs, risks, roles, cases, and types, should also be considered [50] to have better process decisions. There still needs to be a standardized definition for the term process mining perspective, although process mining perspectives have been applied in the Software Engineering domain [48].

3.2 Market Research on Process Mining

Following sources published by top technological research firms and magazines were consulted to gain knowledge on the current trends, practices, and adoption of process mining by organizations worldwide.

- Gartner
- Forbes
- Harvard Business Review
- Fortune Business Insights
- International Data Corporation (IDC)
- EMIS

Market research exposed the applicability of process mining to improve IT operations, process automation, and digital transformation as shown in Figure B.2. The remaining results of the market research can be found in Appendix B.

3.3 Literature Review

The Literature Review (LR) is also a source for the context required to critique, elaborate, and evaluate the literature, enabling it to build new theoretical frameworks [19]. The literature review presented in this section aims to provide insights into how process mining techniques can be applied to improve the efficiency of ITSM operations. The primary rationale behind the below choices of literature study is to perform a literature review with higher scientific value.

3.3.1 Systematic Literature Review Procedure

To ensure the state of the art of process mining application in the ITSM industry, Systematic Literature Review (SLR) was conducted. Understanding the state-of-the-art was necessary for achieving the end goal as it will provide theoretical knowledge. Moreover, the SLR was complemented by an initial search to obtain familiarity with the process mining and ITSM fields, as presented in section 3, followed by an iteration to focus on the application of process mining technology in ITSM context.

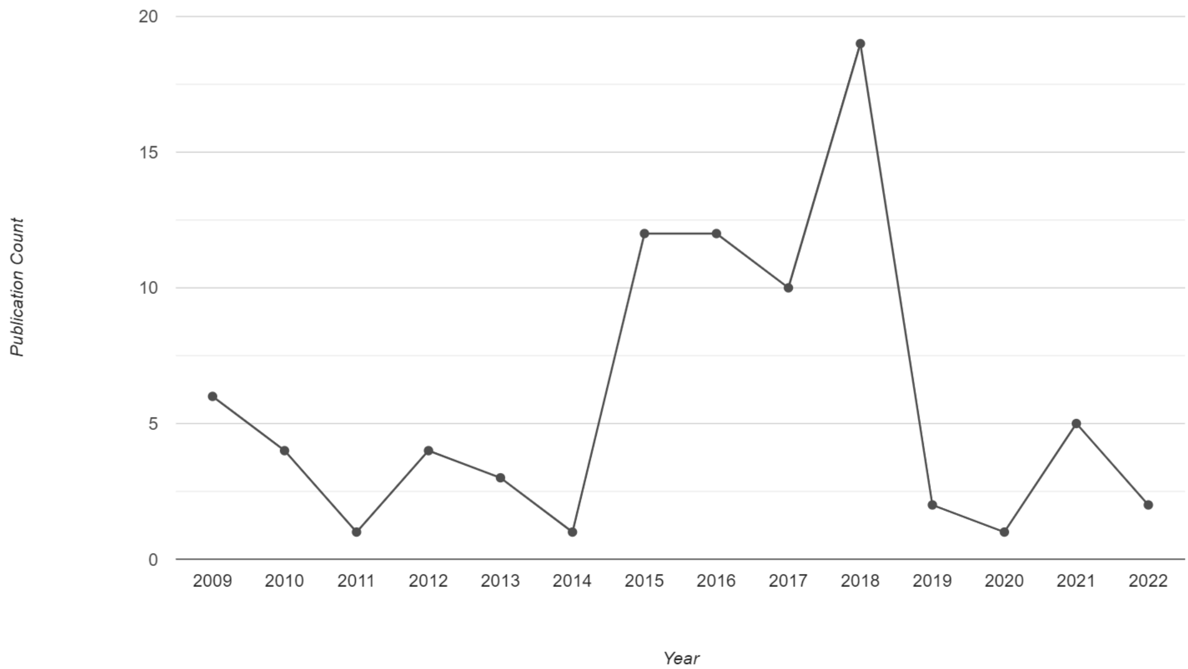

Figure 3.8: Distribution of process mining literature studies in the service management line from 2009 until 2022

The SLR technique proposed by Kitchenham [51] was used to identify, evaluate and interpret all available publications relevant to our research interests in a thorough and objective approach. According to [51], there are three phases in performing a SLR, namely *Planning, Conducting,* and *Reporting*. The process of the SLR for this research can be seen in figure 3.9.

The following search query has been used in the chosen scientific databases mentioned in Table 3.1 for searching relevant studies:

("process mining" OR "workflow mining" OR "process analysis") AND ("IT service" OR "service management" OR "service operation" OR "IT operation" OR "ITSM" OR "ITIL")

e-Database	Search within	Document Type
Scopus	Article title, Abstract, Keywords	Conference Proceeding, Journal
Web of Science	All Fields	Proceeding paper, Article
IEEE Xplore	All	-
ACM Digital Library	Anywhere	Journal, Proceeding

Table 3.1: Scientific Databases, Search Fields, and Document Type for SLR

Consequently, 83 unique literature documents were acquired for this research. Visualizing the count of literature published over the years (refer to graphical figure 3.8), it can be assumed that since the Covid pandemic, there has been a drop in conference and journal articles corresponding to the use of process mining in the service industry.

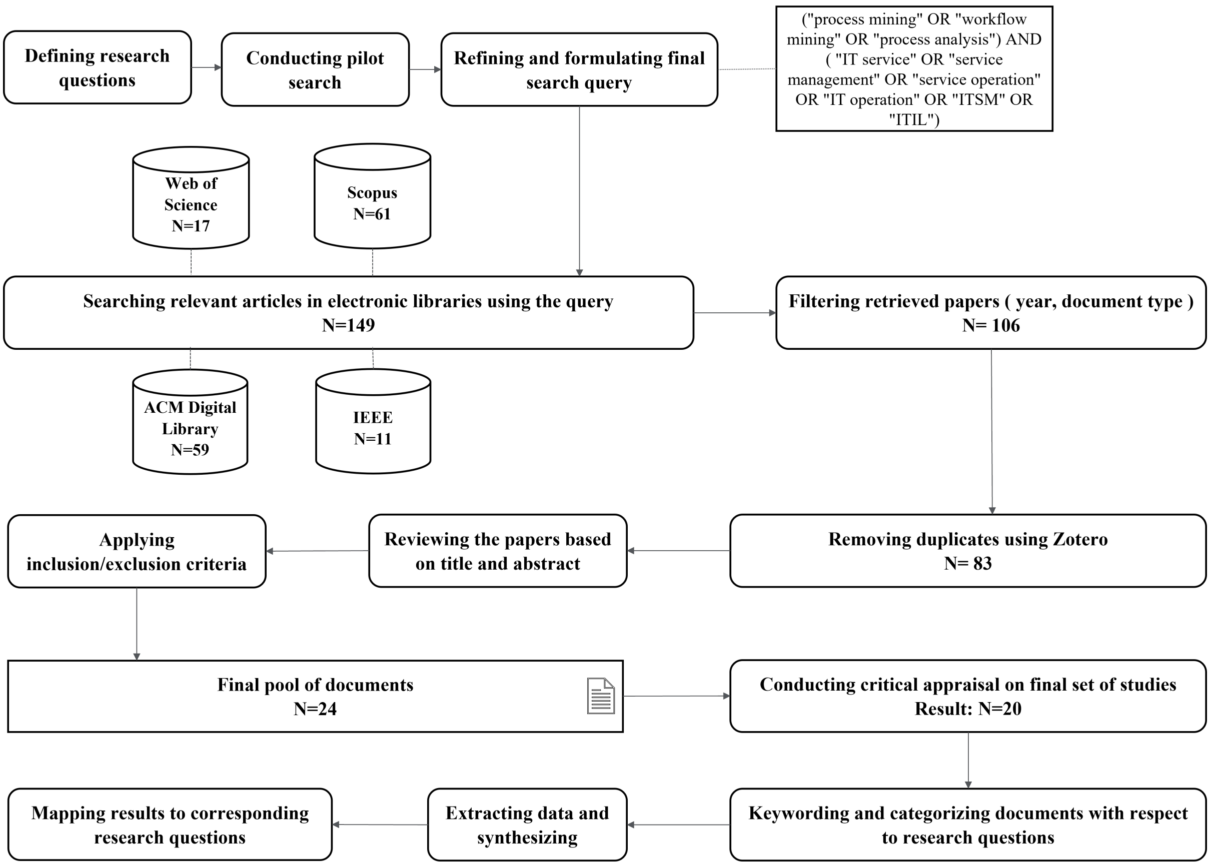

Figure 3.9: Process of SLR during this research

Detailed information of the following on the structure of SLR, can be found in Appendix C:

- Search strategy including the search strings, search query, choice of scientific databases, and inclusion and exclusion criteria
- Critical Appraisal of collected studies including the explanation of quality assessment scoring criteria.
- Data extraction process and synthesis strategy

3.3.2 Semi-Systematic Literature Review Procedure

An additional literature review was conducted to provide information on the topics related to the research question RQ4. The fundamental objective is to propose a framework for the application of process mining incorporating additional elements such as prerequisites and roles required to improve the visibility of inefficiencies in ITSM processes. A SLR counted as too structured and extensive for answering extra information on the research question RQ4. Hence, a Semi-Systematic Literature Review (SSLR) was conducted to explore the existing process mining methodologies. The SSLR is an appropriate research method to localize and understand relevant research works that have potential implications for the studied topic [19]. The process of the SSLR for the research question RQ4 can be seen in figure 3.10. The results of this review method formed a basis for designing the artifact. The search query adopted for this SSLR is **("process mining") AND ("methodology" OR "approach" OR "framework")**

Detailed information on the structure of SSLR, the research questions, the search strategy, and other processes can be found in Section C.4 of Appendix C.

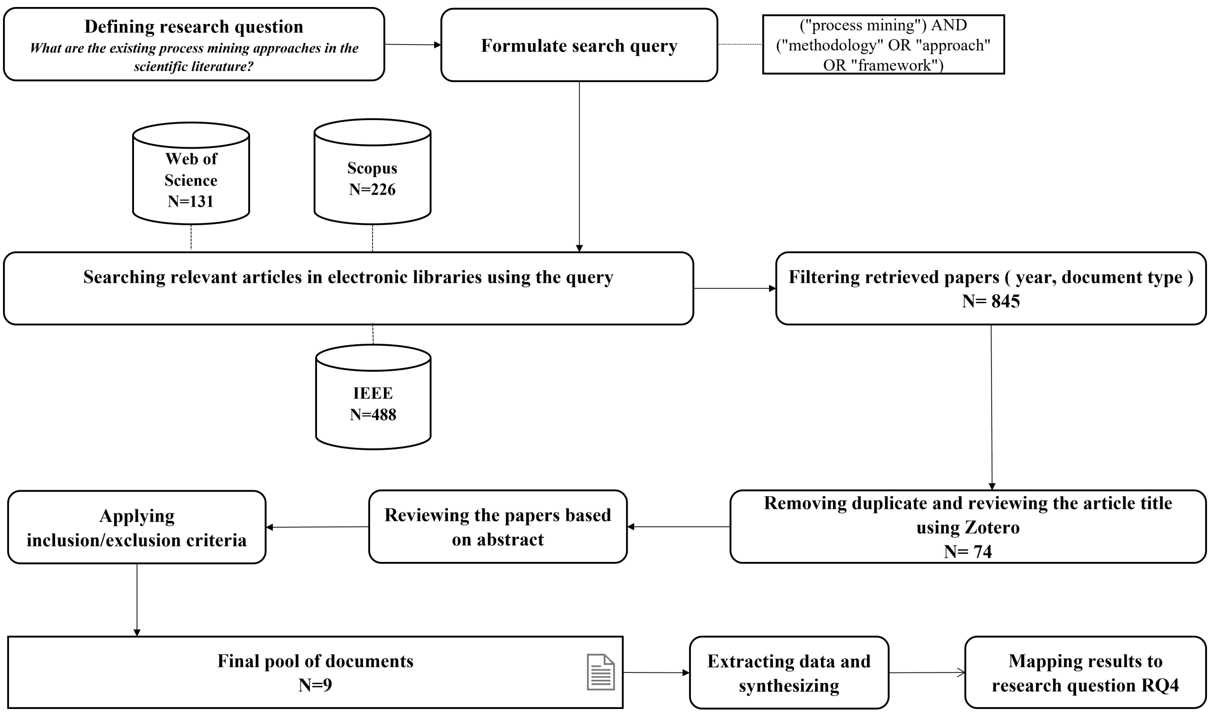

Figure 3.10: Process of SSLR during this research

3.4 Literature Review Findings

The results obtained through the literature review are presented in this section, categorized as sections per research questions of this research and lastly with a section presenting the identified research gaps in the scientific literature.

3.4.1 ITSM Process Improvement Methodologies

In this section, the research question RQ1 is answered:

What are the process improvement methodologies for ITSM processes described in the literature?

ITSM focuses on a set of well-defined and well-established processes that conforms to standards such as ISO/IEC 20000-1 and best practices such as ITIL. To effectively manage IT services, several guiding principles have been provided by standards like the ITIL, ISO/IEC 20000-1 [31], ISO/IEC 15504 [29], Control Objectives for Information and related Technology (COBIT)5, CMMI-SVC [32, 6], Microsoft Operations Framework (MOF) 4.0 [52], and HP Service Management (HPSM) Framework [53]. Based on the systematic review by Mesquida [29], the most widely adopted standards for ITSM are the V2 and V3 versions of ITIL, ISO/IEC 20000, and CMMI-SVC. Even though there are different standards and frameworks available to contribute to the ITSM discipline, ITIL is the most commonly used framework for following best practices of ITSM [29]. Figure 3.11 shows the distribution of primary studies for popular ITSM process improvement methodologies [29]. While ITIL V3 consisted of 26 processes, the latest version released in 2019 called ITIL V4 consists of 34 practices to manage diverse capabilities that underpin ITSM [54].

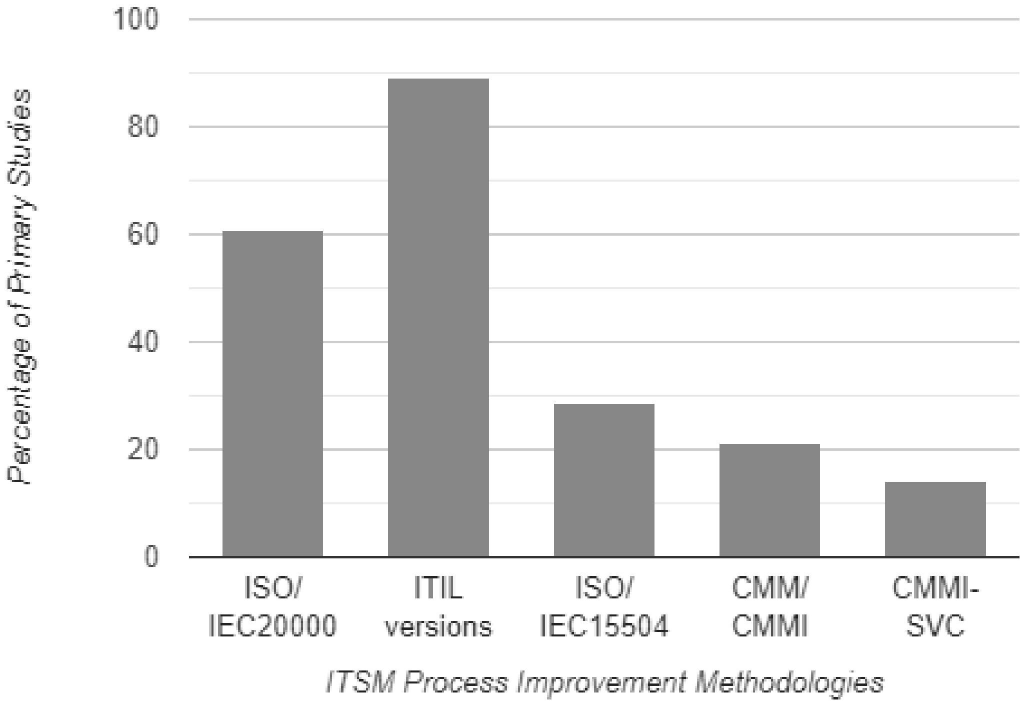

Figure 3.11: ITSM process improvements standards based on systematic literature review by Mesquida et al. [29]

ISO/IEC 20000-1 is an international standard for ITSM [55], which promotes the best practices for planning, implementing, operating, monitoring, reviewing and improving a service management system. CMMI-SVC is a guidance model for improving service quality [32] by applying CMMI best practices. ITIL is a framework that provides detailed best practices for IT activities, and it facilitates the high-quality delivery of IT services at a reasonable cost. ITIL is the de facto standard of reference model accepted for ITSM and is adopted globally [4], even though there are different standards and frameworks available to contribute to the ITSM discipline.

More than 80% of the studies found in this research's SLR focus on practices provided by ITIL, some of which do not mention any indication of the framework or methodology of their ITSM processes.

3.4.2 Process Mining for ITSM Process Analysis

In this section, the following research question RQ2 is answered:

How can process mining be used for ITSM process analysis?

Analysis of actual business processes can be facilitated by gathering insights from process mining applications within an enterprise perspective [56]. Process mining has been used as an analysis technique to identify and quantify customer integration in service companies [57]. A quantitative analysis of event log data from an ERP system for an Austrian IT service company was conducted using process mining to investigate the process performance, and social network of their core business processes [35]. It is found in that study that process mining helps to deliver beneficial insights into the execution of business processes and their performance, dynamics and resource structure. One notable limitation of the study was poor data quality with missing attributes such as timestamps and resource fields. The study sees process mining as an enabler of solid fundamentals for future process improvements. Promising results concerning the applicability of process mining for a service offering process discovery were established in this study. Process mining was also used in a question-driven project to obtain process knowledge and identify incident management metrics to reduce the resolution time [6].

An exploratory analysis of event logs from four different processes specific to incident and request management within an IT platform was performed [9]. It was a curiosity-driven process mining project, meaning the analysis did not aim to adjust, redesign, or intervene in the existing process—the project aimed to gain insights for deeper analysis and a question-driven approach. Early detection of anomalies in business processes prevents intrusion and other associated risks in an organization. Process mining has several approaches to address such problems. Another question-driven process mining project [58] was performed to know how process mining is applied to discover the actual incident management process and check if it complies with the predefined process. This study showed that it is impossible to mine the process within the scope of the a-priori process due to the poor granularity of event data. Process mining was used to analyze the event logs to discover a process model and, in turn, use the derived model for conformance checking.

In a business process, anomalies, also known as outliers, are behaviors that are infrequent or that are not/should not be a part of the actual process [59]. Low-frequency filtering heuristic, sub-sequence context-based analysis and neutral-based analysis are the techniques used to detect outliers in this process. The Inductive Miner Directly follow algorithm was used to discover the process. Process mining was advocated for analyzing user input and their correlation with the resolution time of the requests distinguished input requests into two categories viz, *real* and *tactical* [14]. By leveraging the service level clock state metadata, the analysis helped to reduce the overall user input tickets, thereby improving the user-experienced resolution time and increasing customer satisfaction. *real* input requests are reduced by designing an automated machine learning-based preemptive model. A detection model based on the real-time rule can be designed to decide whether a user input request by an employee was tactical or not.

An automotive company gained insights using process mining techniques for identifying deviations in their IT service processes to improve productivity and service quality [60]. Various techniques of process mining help analyze areas such as ping-pong behaviour, first-call resolution, waiting times, process conformity and performance. Different process mining tools were used, such as Disco for mapping processes to understand data flow and manipulation, Celonis to discover processes for time analysis, and Rapid ProM to conduct performance checking. Process mining is used to analyze the time consumption of process activities, such as waiting time to optimize resource allocation and manage workload or to assess the quality of the service [61].

3.4.3 Process Mining to Improve ITSM Processes

In this section, the following research question RQ3 is answered:

How can process mining be used to improve ITSM processes?

Process mining is generally seen as an enabler of solid fundamentals for future process improvements [35]. Considering the types of process mining as mentioned in section 3.1.5, process mining can be used to analyze, design rapidly, and simulate processes. Thus process mining can be used for the 'plan', 'do', and 'check' stages of the Deming cycle [62] and subsequently, the 'act' stage will be decided and performed by humans either manually or by hybrid intelligence, [58, 63]. Process mining analysis of service processes helps organizations improve the quality of customer service by increasing operational efficiency and customer satisfaction [64]. However, it is important to assess the current situation, as, without baseline measurements, it is impossible to make improvements visible [58]. No literature found during this research described the process of how to leverage process mining techniques to improve ITSM processes.

3.4.4 Process Mining Methodologies

A methodology provides the theoretical framework for best practices in a specific case, from planning to achieving project goals. In this section, various process mining methodologies in the literature are described, and the following research question RQ4 is answered:

What are existing process mining approaches adopted by ITSM practitioners?

A suitable project methodology is a fundamental requirement for the application of process mining to improve business operations successfully. Multiple case studies on process mining can be found in the academic literature, but only a few focus on the process mining project methodology and the managerial implications of its implementation.

The approach adopted by Vázquez-Barreiros iet al. [9] to analyze the process-related information in a data-driven process mining project was as follows: Planning, Data preparation, Conformance analysis, Discovery analysis, and performance analysis. Process mining on incident management process data to analyze the relationship and change of statuses of events to improve or redesign processes used a cascade methodology with the following steps: (1) data extraction from the current process, (2) Data filtering and normalization, (3) Process Mining Analysis (4) analysis of results, and (5) improvement of the process based on observed results [65].

Aalst provided a process mining project methodology known as the L* lifecycle model identifying two complex types of processes viz., Lasagna (structured) and Spaghetti (unstructured) processes for the users of process mining software like ProM [11]. The L* lifecycle model discusses five stages as shown in Figure C.5 in section C.5.3. However, it covers numerous mining techniques, focusing mainly on discovering and analyzing lasagna processes. Inspired by the L* lifecycle model, a case study for a question-driven process mining project [6] followed a few steps as shown in Figure C.6 in Appendix section C.5.4 for successfully analyzing incident

Reference	Planning	Data Ingestion	Data Processing	Description of Event Log Data	Data Mining	Data Analysis	Evaluation	Process Improvement
[35]	✓	✓		✓		✓		
[57]						✓		
[66]				✓				
[59]		✓	✓	✓	✓	✓	✓	
[9]		✓	✓		✓	✓		
[14]		✓	✓	✓	✓	✓		✓
[58]	✓	✓	✓					
[6]	✓	✓	✓			✓		
[65]		✓	✓			✓	✓	✓
[67]	✓	✓	✓		✓	✓	✓	✓
[11]	✓	✓			✓	✓	✓	✓
[45]	✓	✓	✓		✓	✓	✓	

Table 3.2: Approach taken by different research work in the application of process mining

management process and defining metrics for improvement in a global Brazilian organization.

The following approach was taken during the data extraction and processing phase in all of the studies found by the SLR. Process mining of data associated with the IT service tickets consists of data extraction and preprocessing of data to generate event logs. During data preparation, several steps were taken, such as extracting the event log as a CSV file from help desk systems, selecting database fields, preprocessing the file by converting the tab-separated file into CSV, importing the filtered CSV files to MySQL, exporting the database data as CSV file, convert the CSV file to .eXtensible Event Stream (XES) format (a readable file for process mining tools and platforms such as ProM and Rapid ProM) and importing to ProM 6.5.1 [58, 64]. Several preprocessing steps were adopted to generate an event log, such as mapping data fields to event log attributes, to be done carefully depending on the type of analysis intended. A novel technique for mapping events to activities has been developed [68] to be used as preprocessing step that aids the business process intelligence techniques like process mining. It is essential (i) to select optimal granularity levels for activities, i.e. activities should be recorded at the required and desired levels of granularity; for example, a ticket can be closed because of auto-closure if there is no response from the user for specific days or closed by the user after the resolution, and (ii)to resolve inconsistent time stamps by converting time stamps to a fixed timezone based on geographical location. These event logs were used for process discovery and performance analysis [14]. Then, it is crucial to establish a baseline metric with relevant KPIs [58] to optimize the incident management processes. Further, process improvement insights were provided by performing analysis on the process data [64].

Other process mining methodologies in the literature

A methodology to address elements of process mining was proposed to perform quick process diagnostics to cover the outcomes with three perspectives: control-flow perspective, organizational perspective, and performance perspective [69]. The results are obtained after five phases of Process Diagnostics Methodology (PDM): Log Preparation, Log Inspection, Control-Flow Analysis, Performance Analysis, and Role Analysis. PDM is a simple and easy methodology and its scope is limited to cover only few of the process mining techniques. It does not support iterative analysis, which is vital in practical process mining projects. Efforts have been made to consider using process mining in the context of quality management. Graafmans et al. developed a guideline called Process Mining for Six Sigma (PMSS) to support systematic usage of process mining techniques in the context of Six Sigma DMAIC (Define, Measure, Analyze, Improve, Control) Model [70]. The PMSS methodology is shown in Figure C.3.

By offering a framework that encompasses the majority of mining techniques and may act as guidance for process mining projects in various business sectors, PM^2 methodology [67] seeks to solve the shortcomings of the earlier methodologies. PM^2 methodology was introduced as a guide to executing process mining in business projects. Figure 3.12 shows the stages of PM^2 methodology: Planning; Data Extraction; Data Processing, Data Mining & Data Analysis; Evaluation; and Process Improvement and Support [67].

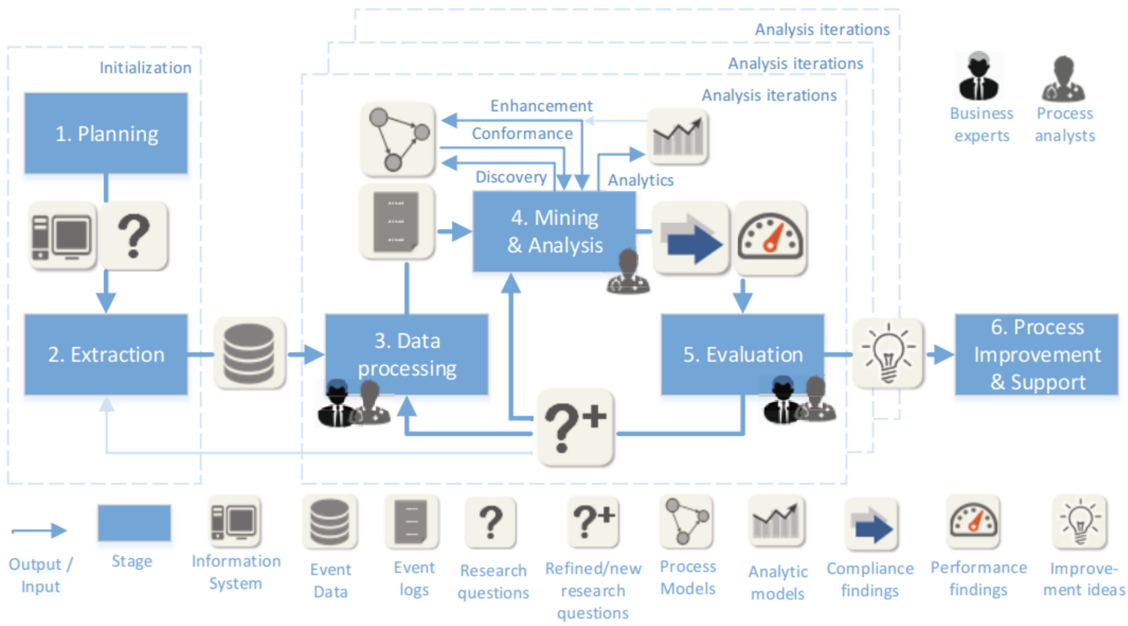

Figure 3.12: PM^2 Methodology [67]

Another generic process mining methodology, Business Process Comparison Methodology (PCM), was introduced for the practical application of process comparison [71] and exclusively focused on the analysis of various processes through the comparison of processes or process variants. Another attempt was made to develop a goal-driven healthcare process evaluation method to develop a methodology for process mining in unstructured processes [45]. This seven-step methodology can be seen in Figure C.4.

The PM^2 methodology is only used as a high-level guideline by iteratively defining and answering questions to improve the performance of the process. Most authors emphasize that no 'one fits' perfect methodology exists. There are many works in developing domain or goal-specific process mining frameworks, including domains such as healthcare [72, 73], warehouse management [74], education [75], and so on, that extend the work of these generic process mining methodologies. However, the PM^2 methodology is considered a proven process mining methodology among the generic methodologies and has been cited as the highest amongst other methodologies.

3.4.5 Prerequisites for Process Mining Application

In this section, the following research question RQ5 is answered:

What are the prerequisites for applying process mining to ITSM process improvements?

Three aspects, referred to as the "three Ps" of Process Mining as shown in figure 3.13, are crucial for the successful application of process mining in any improvement project, namely *Purpose, People*, and *Process Traces* [33]. Before starting any project, the process owner should define the specific purpose or demand. A defined purpose will allow process mining to deliver value by providing insights, which will be made into actionable operations. Next, the right digital mindset is required to ensure operational excellence. Hence right people should be employed in the improvement project to build insights and turn them into actions. Lastly and most importantly, the primary driver of a successful process mining improvement project depends on the identification, collection, and customization of digital process traces. It is essential to understand the concept of Garbage In and Garbage Out as low-quality, and unrepresentative data input for a process mining use case provides little or no value to organizations and often leads to erroneous conclusions [76].

Following pre-conditions were considered while performing process mining on service processes [57, 35, 9, 6, 14]:

- Service processes should be implemented in a PAIS such that the execution of every activity should be recorded.
- Event logs can then be gathered from any business processes, either standardized or customized.
- Service processes that are to be analyzed should at least contain more than one activity.
- Every process instance should belong to a particular process, and every event should refer to a particular case.
- To mine resource perspective, the activity should be assigned to more than one resource executing it.
- Successful process mining with reliable results can be obtained only when finished process instances are included in the process analysis. Hence it is important for start and end timestamps to be identified.
- It is necessary to check if the extracted data is compatible with the selected process mining tool. Thus an event log should be generated before applying process mining techniques.
- In case of lack of reported information, it is best to replace the null values with estimates to regard the events which may be relevant.
- It is important to formulate KPIs, as, without them, it is impossible to check conformance.

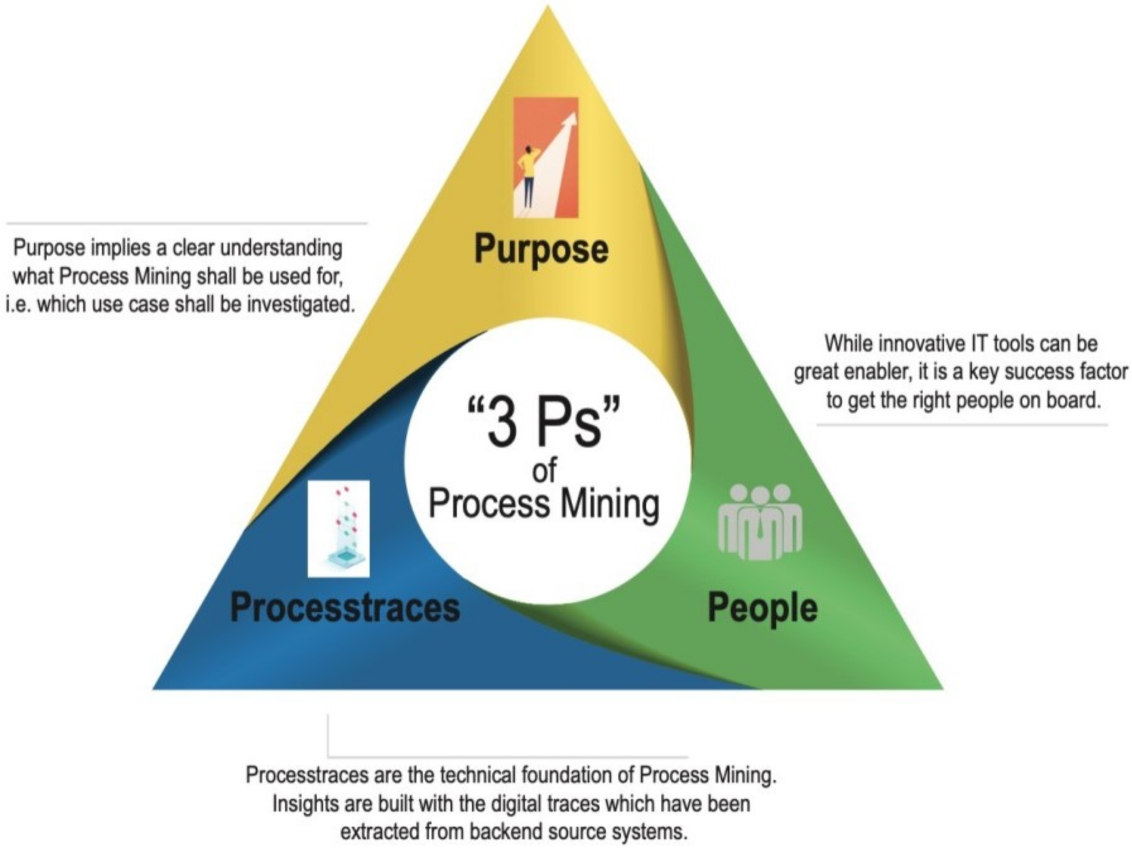

Figure 3.13: Three Ps of Process Mining as described by Lars Reinkemeyer [33]

- To perform a conformance checking, the desired business process should be available as an apriori process model so that discrepancies between modelled behavior and observed behavior can be identified and investigated.

Most of the literature found during the SLR stated that XES is the event log format for mining a process using process mining tools such as Disco and ProM. XES is the de facto format for process mining, which was adopted by IEEE Task Force on Process Mining [11]. An XES document consists of a log containing traces of a sequential list of events related to a particular case. ProM has packages to convert different input types, such as CSV, into XES. Hence there are less strict requirements for input data, unlike Celonis and Disco [58]. Table 3.3 shows the usage of process mining tools and data formats across different studies during this research. However, tools available in the market, such as Celonis, have evolved not to pose any such format implication as long as the event data is SQL readable.

3.4.6 ITSM process candidates for applicability of process mining

In this section, the following research question RQ6 is answered:

Which ITSM processes are suitable for improvements using process mining?

The underlying relationship between variables was identified using process mining and simulation combined, and visual models can be developed. Two ITSM processes, namely Change Management and Incident Management, were covered during the case study to design a predictive model to support lessening the workload impact of Incident Management operations [66]. Process mining has been used to discover anomalies in the process by exploring an incident management event log [59].

Reference	Tools	Data Format	Information system
[35]	Minit	CSV	ERP
[66]	ProM	CSV	NA
[59]	PM4PY library	NA	ServiceNow
[58]	ProM	tab-separated text file converted to CSV	HSPM
[6]	Disco	XES	HPSM SM9 Incident Management Tool
[60]	Disco, Celonis, Rapid ProM	NA	NA
[64]	Disco	CSV	NA
[12]	ProM	CSV	NA

Table 3.3: Tools and Data Format used by researchers

3.4.7 Research Gaps

During the research process to answer RQ3, it has been found that no literature found during the literature review described the process beyond delivering insights for ITSM process improvements. Process Mining has been leveraged in improving the process using Six Sigma DMAIC approach [70]. There exists research shows how Process Mining can check compliance of as-is processes with to-be processes through a Continuous Process Improvement reference model, followed by the ITIL V3/2011 seven-step Continual Service Improvement procedure [12]. ITIL also released its fourth version by Axelos in the year 2019 [2]. With the service management platforms offers by multiple PAIS vendors, the process traces of every service operations could be actively tracked for data-driven process analysis and improvements. Such practices would facilitate the application of process mining techniques, as the minimal data requirements (as mentioned in Section 3.1.4) and other requirements can be easily gathered with modern cloud-based workflow automation platform such as ServiceNow. Nevertheless, it clearly indicates the first research gap as,

A need for structured methodology guiding how and when to leverage process mining techniques, and the inputs and right stakeholders required, to effectively perform ITIL Continual Improvement activities.

The process mining methodologies mentioned in section 3.4.4 have a few limitations and are not comprehensive and agnostic for every project. PDM does not consider business planning and domain knowledge in its approach. L* lifecycle focuses on process discovery and does not offer flexibility and iterations. The activities are assumed to follow in a sequence, which is rarely true in complex project scenarios. The latest proven process mining methodology in the literature was PM^2 methodology [67], which was developed in 2015. PM^2 was built around an academic tool, ProM. There has been much improvement in the field of process mining after the existence of PM^2 methodology in 2015. For example, it has data extraction as one step out of six. Today, process mining tools like Celonis offer a direct connection with the data source. The data is ingested based on pre-scheduled data jobs, supporting day-to-day monitoring of activities in a process. This shows that PM^2 is tool-independent. Moreover, the PM^2 methodology ignores the importance of business considerations and starts to identify and translate goals to research questions before gathering the project team. Though it is possible to redefine the questions after the team is formed, logically, it is only sensible to have the right people on board and then focus on the problem areas. Lars et al. insist on 3Ps - people, purpose, and process traces for the success of process mining projects [33]. It has been seven years, and the field of process mining emerged with lots of capabilities and market tools that offer more features which call for a refined framework. Consequently, the process mining approaches from the literature will not be sufficient to cover the seven steps of ITIL Continual Improvement practices for covering the research gap identified earlier. This calls for another research gap identification as

A need for a process mining methodology with all elements such as inputs and stakeholders given the Research and Development advancements in the process mining domain

Also, the studies identified during this research's literature review did not cover the information on the effort required in terms of time and cost, for successfully implementing a process mining project. This provides the following research gap that requires attention.

The analysis of effort required for a successful process mining improvement project.

Every business process improvement with the enablement of cutting-edge technology requires a business case development that shows the aspect of value in the investment of the solution. From the process of the research's literature review, another research gap in the fields of this research is to

Value model for the application of process mining techniques for different ITSM operations.

Further, the following chapters of this thesis will address the approach undertaken for fulfilling the first two of the aforementioned research gaps found during this literature review.

To develop a process mining framework with elements such as pre-requisites, roles required and output, that supports organizations adopting the ITILV4/2019 Continual Improvement Model to perform process improvement activities using process mining techniques effectively.

3.5 Summary

- Understanding of Business Process Management is vital to describe process mining. The typical phases of a business process have been explained in Section 3.1.1.
- Business Process Improvements require detailed analysis of as-is processes and issues that obstruct optimal results.
- ITSM focuses on end-to-end delivery of IT operations, such as delivery and support of services to end users. ITSM is crucial for every business to promote business and IT convergence, drive IT efficiency, increase consumer satisfaction, support constantly changing regulatory compliance, and reduce the lifecycle of incidents.
- ITSM shares common concepts with process improvement methodologies such as Six Sigma, TQM, and Business Process Management. ITIL has been considered the de-facto and proven standard of reference model accepted for ITSM.
- Digital process mining is a data-driven approach that provides a transparent, comprehensive perspective of all activities within a company's business processes based on the event logs tracked in the PAIS such as *ServiceNow*. Process mining eliminates the errors and time consumption from manual process mapping, allowing companies to optimize, innovate, and help accelerate products and services and fundamental business operations with the help of the enormous amounts of digital footprints.
- Such digital footprints are referred to as *Event Logs* with three pieces of information, namely object ID, an activity, and a timestamp, which collectively form the basis for building the digital twins of the business operations.
- Three main types of process mining include Process Discovery, Conformance Checking

and Process Enhancements. Other process mining capabilities are discussed in Section 3.1.5.

- Based on the behavior of the event logs' characterization, various process mining perspectives support process analysis, such as control flow, resource, time, data, and functional perspectives. Control flow is the most applied perspective as it is the basis for further process analysis. Different perspectives should be considered to provide impactful business decisions.
- Market research based on the publications by top technological research firms and magazines revealed the global trends, practices, and adoption of process mining. Gartner's analysis of process mining use cases exposed the applicability of process mining to improve IT operations, process automation, and digital transformation, as shown in Figure B.2.
- Literature review has been conducted to provide scientific insights into how process mining techniques can be applied to improve the efficiency of ITSM operations. The literature review's process and results have been discussed in section 3.3. The literature review also enabled finding answers to the sub-research questions of this research.
- Additionally, research gaps were identified and discussed in section 3.4.7.
- The next chapter discusses the approach undertaken for fulfilling one of the research gaps identified during the literature review of this research, i.e., To develop a method that supports organizations adopting the ITILV4/2019 Continual Improvement Model to perform process improvement activities using process mining techniques effectively

Chapter 4

Design and Development of PM4CSI V0.1

The literature study has been adopted to understand how process mining can be leveraged to improve ITSM processes. The following sections of this chapter will discuss the development of the PM4CSI V0.1 in detail. Though ITIL refers to its improvement framework as the Continual Improvement Model, the framework in design is intended for the improvements of ITSM operations. Hence the framework is called Process Mining for Continual Service Improvement (PM4CSI). Firstly, it is crucial to understand ITIL Continual Improvement Model, the popular improvement framework used in the ITSM industry. Secondly, a process mining approach has to be designed based on knowledge derived from the scientific literature. Finally, the phases in the process mining approach have to be mapped to the steps in the ITIL Continual Improvement Model. Such mapping would allow us to distinguish how and in which steps of the ITIL Continual Improvement Model, the capabilities of process mining can be leveraged. Consequently, the initial version of PM4CSI has been developed.

4.1 ITIL Continual Improvement Model

Operational excellence is considered a factor for competitive advantage in organizations, and companies are constantly seeking ways to optimize their processes. In IT, best practices frameworks such as ITIL are adopted for process optimization. It is the most widely accepted and adopted guidance framework on ITSM. It is constantly updated with the advancements in information and technology, reshapes its established practices of ITSM, and has led the ITSM industry with training, guidance, and certifications for more than 30 years now [2]. It embraces new Ways of Working (WoW), such as Lean, Agile, and DevOps. ITIL 4 provides high-level guidance and support to organizations for addressing new service management challenges and utilising the potential of modern technology [2]. It is designed to ensure a coordinated, flexible, and integrated system for the effective governance and management of IT-enabled services [2].

Continual improvement is a concept related to the risk management framework [77]. The difference between 'çontinuous' and 'continual' is that *an event is described as continuous when it occurs continuously over time, as opposed to continual when it occurs at regular intervals.* In ITIL, service improvements are continual and not continuous use as a stability period is preferred following each improvement. Unless stabilization is achieved, the services offered will suffer from various SLA breaches and other challenges.

ITIL Continual Improvement Model [2] aims to derive measures to be adopted to improve the quality of the service by learning from historical successes and failures. It provides best practices for achieving large-scale, incremental improvements in the quality of the services, business continuity, and operational excellence. With the help of KPIs, ITIL serves as a metrics-driven process for evaluating and benchmarking service performance. ITIL Continual Improvement Model [2] provides a structured method and high-level support to implement improvements in an organization. Figure 4.1 presents an overview of ITIL continual improvement model. The scope and description of each step can be modified based on the type and subject of the improvement. The model is flexible such that the organization can adjust the steps as per its culture (i.e., *Agile or Waterfall*) and objectives [2]. The steps of the Continual Improvement Model are not mandated to be carried out linearly, and critical judgement should be applied when using this model.

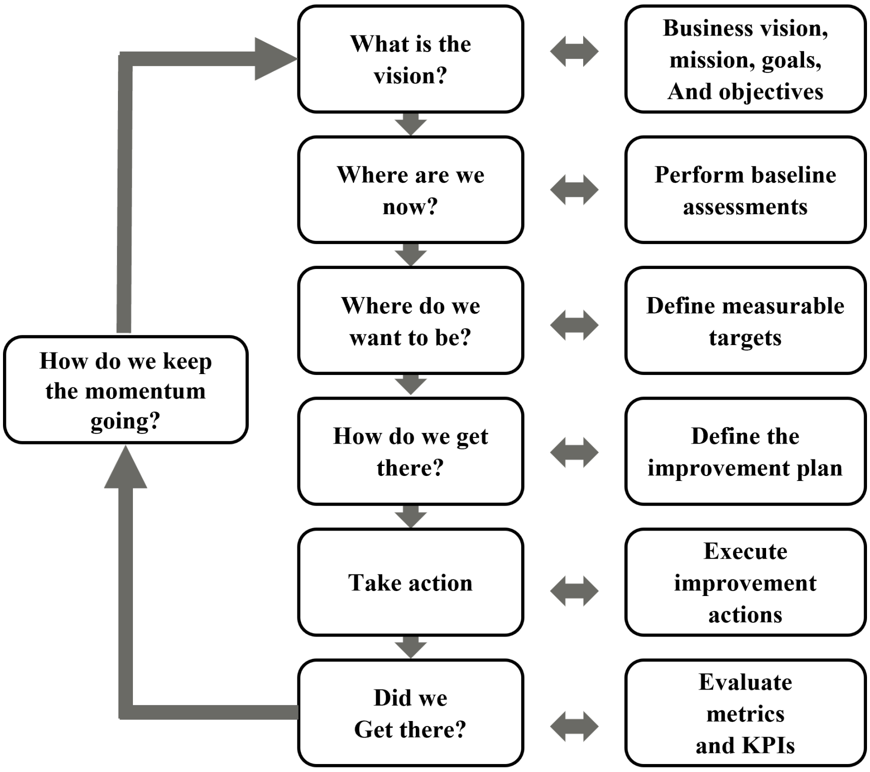

Figure 4.1: ITIL Continual Improvement Model [2]

The steps for the continual improvement model as described in ITIL v4 foundations manual [2] are as follows:

What is the vision?

- The main focus areas of the first step are (i) understanding the vision and goals of the organization, such that they can be cascaded to a specific department, team, and/or business unit; (ii) Creating a high-level vision for the improvement project. It is crucial to ensure the expected value is realized through the improvement initiative and understood and agreed upon. The stakeholders should be identified, and their roles should be understood and clearly defined at this step.
- Skipping this phase might result in improvement projects not aligning with the organisation's objective or focusing on non-value-adding activities.
- During this step, it is essential to apply the following ITIL guiding principles: *Focus on value, Collaborate and promote visibility,* and *Think and work holistically*.

Where are we now?

- The success of any improvement initiative depends on an accurate understanding of the starting point and the project's impact. A primary element is a current state assessment based on objective measurement. The evaluation of the current state includes assessing the services, users' perception of the value received, people's competencies and skills, processes, and technological capabilities. This would serve as a proper measurement of the improvement level achieved by comparison with the start state.
- Skipping this step would result in a lack of understanding of the current state and a lack of objective baseline measurement, causing difficulty in measuring the effectiveness of the improvement initiatives
- During this step, it is important to apply the following ITIL guiding principles: *Start where you are*, and *Collaborate and promote visibility*.

Where do we want to be?

- In this step, a gap analysis is performed to evaluate the scope and the journey required from the current state to achieve the project's vision. ITIL v4 insists that improvement is just the goal and not a perfection state. It is important to define prioritized improvement actions based on gap analysis to achieve the vision. Along with KPIs and critical success factors, improvement objectives are set.
- Skipping this step makes the target state unclear.
- During this step, it is important to apply the following ITIL guiding principles: *Progress iteratively with feedback, Think and work holistically, Keep it simple*, and *Optimize and automate*.

How do we get there?

- Based on the vision of the initiative and the current and target states, an improvement plan for addressing the challenges is co-created with the knowledge of SMEs in this step.
- Skipping this step might result in the failure of the execution of the improvement project. Failed improvement initiatives make it difficult to seek support for future improvements.
- During this step, it is important to apply the following ITIL guiding principles: *Progress iteratively with feedback, Think and work holistically, Keep it simple*, and *Collaborate and promote visibility*.

Take action

- In this step, the improvement plan is executed. ITIL recommends an agile approach by experimenting in iterations and working on the feedback. Improvements can be big initiatives or small initiatives, which is significant. It is essential to continuously focus on measuring progress towards our target, risk management, and ensuring transparency and overall awareness of the initiative.
- During this step, it is important to apply the following ITIL guiding principles: *Progress iteratively with feedback*, and *Collaborate and promote visibility*.

Did we get there?

- In this step, the targets are checked to ensure that the objectives have been reached. It is essential to validate the success by checking and confirming the progress and the value.
- Skipping this step makes it difficult to ensure that the desired outcomes were achieved and may result in loss of feedback from iterations.
- During this step, it is important to apply the following ITIL guiding principles: *Focus on value, Collaborate and promote visibility,* and *Think and work holistically*.

How do we keep the momentum going?

- In this step, if the project has delivered the expected value, the improvement initiative's focus should be shifted to celebrating and marketing the successes. Leadership should guide the project teams to reinforce new work methods into the routine and establish new behaviors. In case of failure of the improvement project, the failure reasons and lessons must be documented and communicated to the stakeholders involved.
- Skipping this step would make the improvements remain isolated, and the progress becomes obsolete over time. Consequently, embedding continual improvement in the organization's work culture becomes difficult.
- During this step, it is important to apply the following ITIL guiding principles:*Focus on value, Collaborate and promote visibility, Optimize and automate,* and *Think and work holistically*.

4.2 PM4CSI V0.1

The primary goal of this research was to develop a new framework that supports ITSM practitioners to assess and perform their processes using process mining techniques. Section 3.4.4 describes the process mining approach and/or methodologies proposed in the scientific literature to provide guidance in using process mining techniques. However, these methodologies need an apparent link with the phases of service improvement and management frameworks, in our case ITIL v4 Continual Improvement Model. Hence, for the initial version of PM4CSI, a process mining methodology as a basis is required to map the process mining phases to the seven steps of the Continual Improvement Model of ITIL v4 to align it with the tasks and focus of a continual improvement initiative.

4.2.1 Development of a Process Mining Approach for Service Improvement Projects

Based on the theoretical knowledge gathered during this research project, it is evident that certain activities are performed to successfully apply process mining in improvement projects [67, 35, 58, 14, 11, 9, 6]. The following phases are identified as sequential steps taken in process mining projects:

Project Planning

This phase aims to kick-start a project and determine the research questions for the process analysis and target improvements. During this phase, it is important to carry out the following activities:

- Selecting and understanding business processes based on process characteristics and data quality. Suppose process improvement is the main project goal. In that case, it is essential to consider only processes for which the executions can be influenced or adapted based on the insights from process mining analysis. The process models need to be described in a standard modelling notation, such as a Business Process Modelling Notation (BPMN) format.
- Formulating (abstract) business research questions.
- Composing the project team with roles such as business owners, process experts, IT system experts, and process analysts.
- Establishing a baseline with relevant KPIs.
- Selecting process mining tool to be used for the improvement project.

Data Ingestion

The objective of this phase is to obtain and import data from one or more sources to a target site for further processing and analysis. The phase termed as *Data Ingestion* is the data extraction process from different sources and storing it in a centralized space called a data lake. Modern process mining tools facilitate the direct ingestion of process-related event data into the tool with the concept of adaptors or extractors. During this phase, it is essential to carry out the following activities:

- Determining the scope of the data, such as deciding which data attributes impact the problem of analysis, within which period, and at which level of granularity.
- Extracting the event data from data source systems.
- Understanding of the data description and the process associated with it. Tacit knowledge can be transferred between process analysts and business experts through brainstorming workshops or interviews.

Data Preparation

The objective of this phase is to create event logs and process them to prepare an enriched event log for process analysis. During this phase, it is important to carry out the following activities:

- Ensuring the extracted file to compatible with the process mining tool.
- Preparing and filtering enriched event logs by cleaning up data and creating aggregate events, for example, adding an artificial start and end activity timestamp to each trace.
- Mapping the attribute to case level and event level attributes.
- Including only necessary activities to avoid complexity and spaghetti process models.

Process Discovery

This phase aims to visualize a process map as a directed flow graph. Algorithms like Inductive Miner Directly Follows (IMDF) were used to discover fact-based process models as output. A digital twin of the actual process and value streams is the valuable output of this phase.

Process Analysis

This phase aims to analyze the process to answer the research questions and/or exploratory analysis of the overall view of the business processes. Additionally, results are obtained, which can be used to enhance process models. During this phase, it is important to carry out the following activities:

- Formulating more specific research questions, such as how frequently was a particular activity executed? In how many cases can an activity be found?
- Postulating different variants of the process
- Performing different kinds of analysis such as conformance checking, performance analysis, variant analysis, dimensional analysis, anomalies detection, and organizational analysis. Other analysis techniques can be applied to the event logs and process models, such as data mining or visual analytics.
- Defining KPIs and PPIs as, without metrics, it is difficult to check if the process is conforming to expectations.

Deliver Insights

This step aims to deliver the findings and relate these findings to improvement ideas to achieve the goal of the improvement project. During this phase, it is important to carry out the following activities:

- Delivering the findings.
- Ensuring the correctness of findings with the involved stakeholders.
- Providing information on metrics related to the use and improvements of processes to the organization.

Process Improvement

This phase aims to tap the potential for improvements identified in the previous phase. The main motivation of any improvement initiative with process mining is the improvement of the processes. The idea is to eliminate, extend, or improve the existing process model. During this phase, it is important to carry out the following activities:

- Implementing the potential use cases of improvements. The actual implementation of the process improvement is a different project and is treated as a black-box process as it is not under the scope of this research.

Measure Results

The *Measure Results* phase was added to this process mining approach to monitor the progress quantitatively. It is essential to measure the results of the improvement projects to gain the trust for continual improvement of other processes in an organization.

Support Continual Improvement

The *Support Continual Improvement* phase was added to this process mining approach as process mining provides operational support by dynamically detecting issues in the running process instances. Aalst's L* lifecycle model depicts three kinds of operational support activities, namely *detect, predict*, and *recommend*. However, it is essential to have a structured process and high-quality results to implement this phase in an organization.

4.2.2 Mapping Process Mining Approach with ITIL Continual Improvement Model

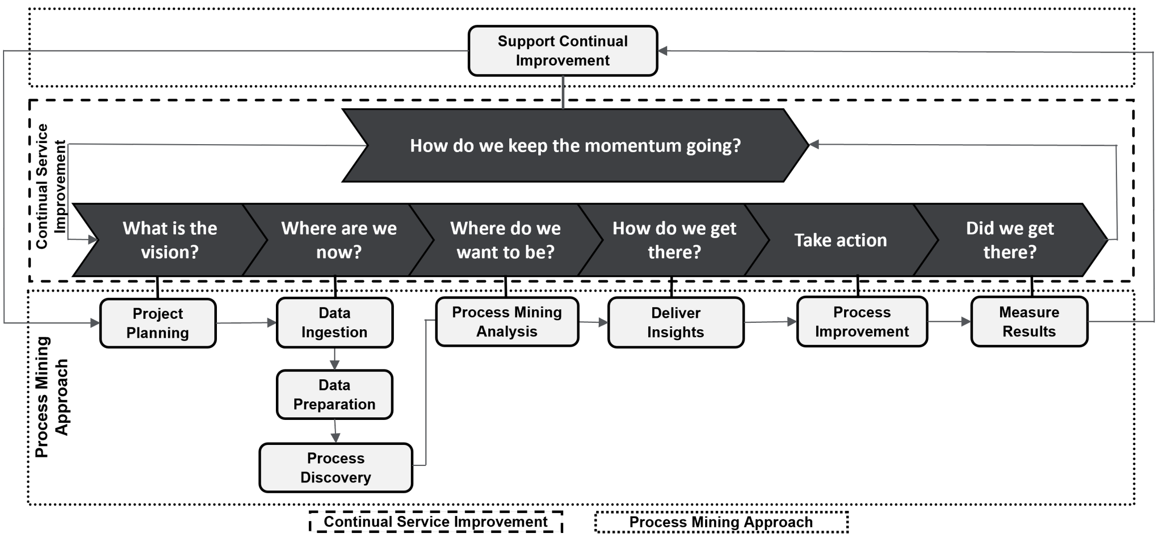

Figure 4.2: PM4CSI V0.1

Based on the information presented in the sections 4.1 and 4.2.1, the process mining approach and ITIL Continual Improvement Model has been mapped, such that the objective and tasks of each of the phases of the process mining approach best align with each of the Continual Improvement Model steps. Figure 4.2 shows the mapping of steps from ITIL's Continual Improvement Model to phases of the process mining approach designed in the section 4.2.1.

When a researcher's beliefs or expectations affect the research design or data collection procedure, the output is bound to a bias called researcher bias. Confirmation bias is an inclination to retain or abandon a favoured explanation, which can undermine the trustworthiness of professional research endeavours [78]. To avoid the *researcher's bias* on the design of the PM4CSI V0.1, two series of interviews with experts from the field of process mining and ITSM were conducted. The following chapters will describe the process to output a refined and evaluated PM4CSI version. The activities in each phase and the list of the prerequisites, outcomes, stakeholders involved, and required tools for each phase suggested by papers from the literature review are also parts of the artifact in design. However, due to the ambiguity of such information from the academic literature found during the literature review, they have not been included in the PM4CSI V0.1. Excluding this part of artifact also reduces the possibility of *confirmation bias* in the data collected from the interviews conducted during the framework refinement phase.

4.3 Summary

- ITIL has been adopted as best practices framework for process optimization. ITIL's Continual Improvement Model provides a structured method and high-level support to implement improvements in an organization through seven steps, as shown in Figure 4.1. Section 4.1 discusses the seven steps of this model in detail.
- Since the process mining approach proposed in the scientific literature lacked a link to the seven steps of the ITIL Continual Improvement Model, a process mining methodology has been developed from the conceptual knowledge gathered during the literature review of this research. Consequently, a process mining methodology consisting of nine phases has been developed.
- These nine phases have been mapped with the seven steps of ITIL Continual Improvement Model as shown in Figure 4.2, which has been referred to as PM4CSI V0.1.
- The next chapter addresses the process to output a refined and evaluated PM4CSI framework through two series of expert interviews conducted to avoid researcher and confirmation bias. Such framework refinement interviews also facilitated gathering information related to the activities and the list of the prerequisites, outcomes, and stakeholders involved in each of the nine phases.

Chapter 5

Framework Refinement

This chapter presents the process to refine the initial version of PM4CSI, PM4CSI V0.1. Section 5.1 discusses the rationale and process of the expert interviews for framework refinement, including the interview design and transcript analysis procedure. Sections 5.2 and 5.3 discuss the results from the two series of expert refinement interviews, which led to the design and development of the refined version of PM4CSI V1.0.

5.1 Expert Interviews

The Systematic Literature Review (SLR) conducted during this research has contributed significantly to the design and development of PM4CSI V0.1. The SLR provided the foundation for mapping the steps of ITIL Continual Improvement Model with the steps performed in process mining projects. Firstly, only limited studies were available during the SLR of this study and only a few were empirically validated. However, no research followed any standardized methodology, even the popular ones in the field of process mining such as L* lifecycle model [11], or PM^2 methodology [67]. Additionally, only a few of the activities were documented in the publications, and those research articles focused more towards evaluating the value of process mining applications in IT service improvements. Nevertheless, considering the novelty of the research area, i.e. application of process mining to assess and improve ITSM sector, the identification of activities performed in process mining initiatives proved ambiguous, insufficient, and lacked complete guidance on how to carry an end-to-end process mining project in ITSM sphere. Thus, the data on the activities performed in a ITSM improvement initiative using process mining technology were qualitatively collected through interviews.

The rationale behind choosing expert interviews as a qualitative data collection method was to have clarified research output, and collecting data via questionnaire does not best fit the purpose of framework refinement. Additionally, interviews offer the possibility to expose information that would be impossible to access using quantitative methods, such as questionnaires [79]. Interviews are an effective qualitative research method when the researcher is interested in collecting 'facts' [80] or gaining subjective insights from the experts' opinions and experiences [79] for formulating a conceptual theory.

5.1.1 Interview Design

The participants of the interviews were selected to have diverse experiences and from different organizations. Hence, using pre-coded questions helps improve the validity and generalizability of the results [81]. However, additional sub-adaptation questions or prompts ensure flexibility and allow the interviewee to provide an adequate answer to the central question [80]. Therefore, semi-structured interviews were best for refining PM4CSI. Since a novice researcher conducted this research, open-ended qualitative questions were formulated before the actual interview. It is essential to consider several sources of variability as they could influence the findings, such as selecting experts with different experiences, locations and organizations. Also, it has been recommended to continue the interviews with different experts until theoretical saturation has been attained [82]. Data saturation is when necessary conclusions can be drawn from the data collected, and any further data collection will not produce value-added insights. Hence two rounds of interviews were planned, with thirteen experts to ensure the validity of the interview process by reaching the point of data saturation.

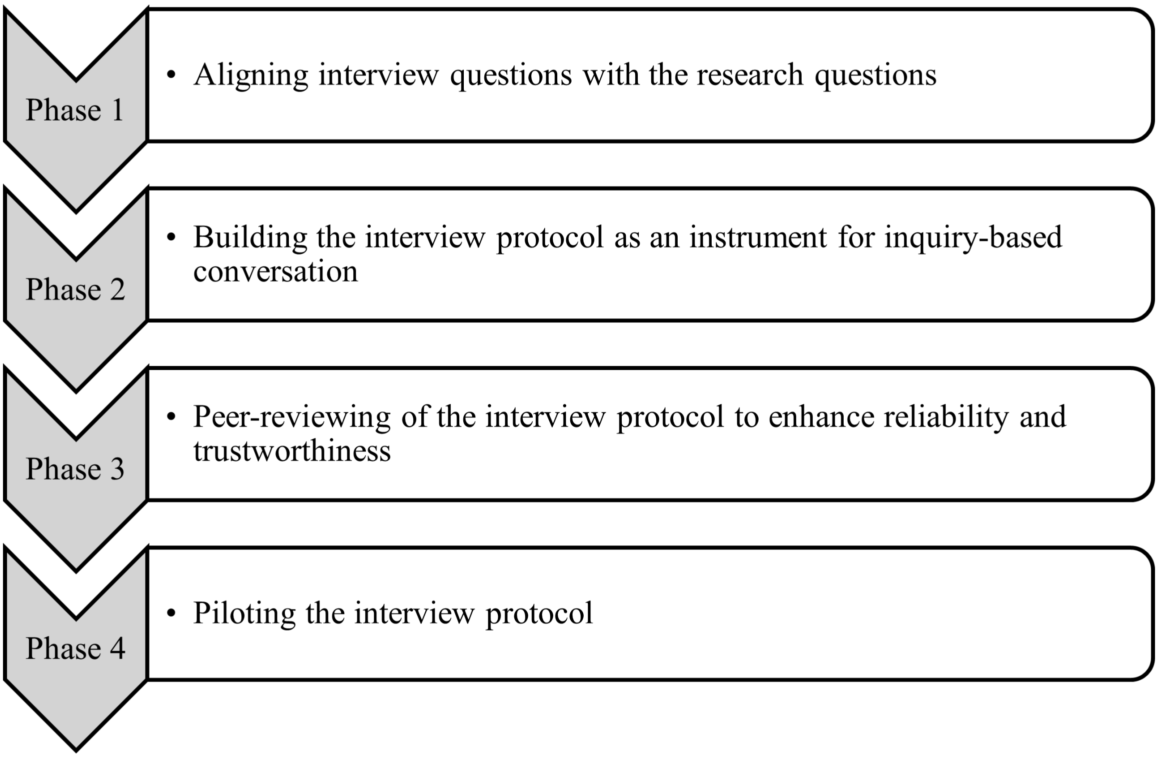

Figure 5.1: Interview Protocol Refinement framework used during the framework refinement interview process

The goals of the framework refinement experts interviews are (1) to confirm the selection and mapping of phases in process mining for continual service improvement approach, (2) to confirm the activities in each phase and (3) to identify the inputs and stakeholders required for each phase with possible outcomes. It is essential to design an interview protocol before the interviews. Interview protocol ensures that data collected during interviews with different experts are in a similar way [81]. The design of the interview protocol followed the Interview Protocol Refinement framework [83], which consists of four phases as illustrated in figure 5.1. During the first phase, the questions of the interview protocol were drafted, aligning with research questions RQ5, RQ6, and RQ7. The interview protocol has been divided into sections which could simplify the data analysis of the interview results significantly, as the results will most likely be summarised per question. The interview protocol has been divided into the following sections:

- Introduction - To properly introduce each other, gain approval to record the interview session, clarify the purpose of the interview, indicate the duration of the interview, address the terms of confidentiality, and understand the interviewee's profile in detail to validate the generalizability the results of the respondents.

- Present the framework - To explain the research and link it to initiate the central focus of the interview.
- Phase analysis - To gather data on all the activities and requirements in each phase. Here, the researcher must pose only one question at a time.
- Effect questions - To ensure and understand the existence of similar artifacts and their effect.
- Relevance and Demand - To understand the relevance and demand for process mining technology
- End Card - To provide an opportunity for closure [83]

During the second phase, the interview protocol was composed of research questions reformulated as interview questions that followed the social rules of ordinary conversation. To promote the flow of conversation, prompt and follow-up questions were included in the interview protocol. Following this phase ensured that the interview protocol provided a general flow of conversation and acted as a guiding instrument for data collection. During the third phase, the interview protocol was peer-reviewed by a process mining expert and with the supervisors of this research. With the peer-reviewed, inquiry-driven interview protocol, the pilot interview was conducted with two colleagues who have been aware of and closely connected with this research. Hence, the transcripts of the pilot interviews have been excluded from this research to avoid potential bias. The pilot interview results have been described in Appendix D.1.1. The third and fourth phases were carried out essentially to rule out the researcher's bias [84].

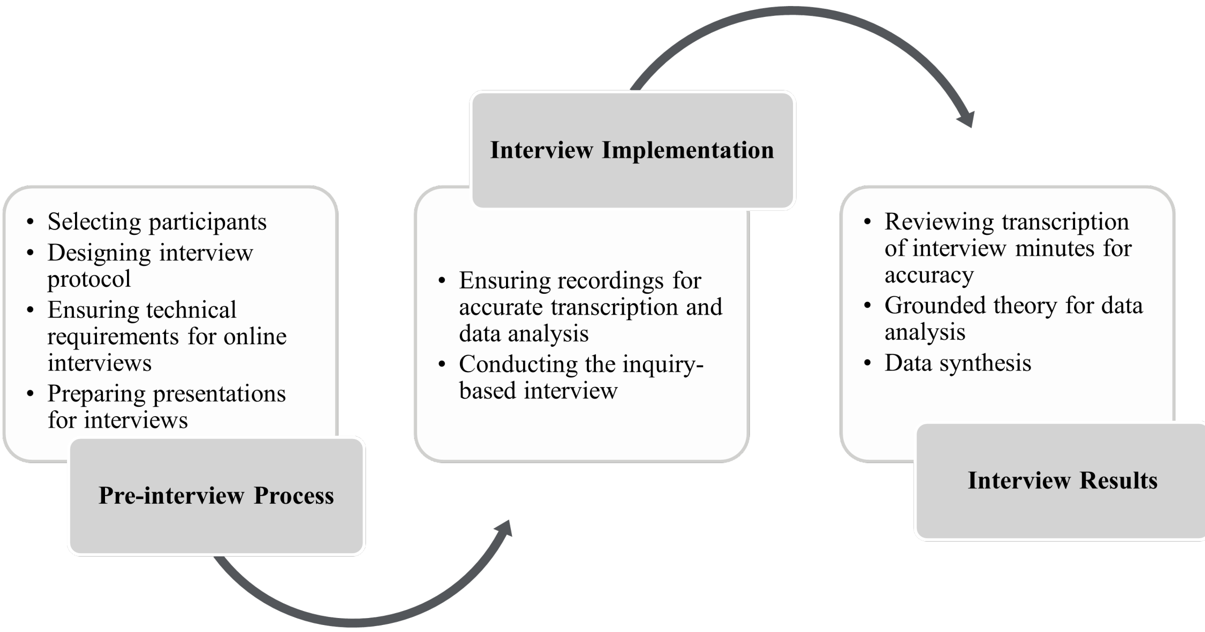

Figure 5.2: Expert Interview Process for PM4CSI Framework Refinement

The two rounds of refinement interviews were conducted at two distinct moments of the study. To clarify the terms used for defining the framework refinement interviews in this report, the two rounds will be referred to as *First Round Interview* and *Second Round Interview*. Both rounds of interviews provide data to research questions RQ5, RQ6, and RQ7. During the *First Round Interview*, the focus was on identifying possibilities for modifications in the PM4CSI V0.1 and collecting data that would be useful to formulate the list of activities, prerequisites, outcomes, stakeholders involved, and other requirements in each phase of PM4CSI. Additionally, information regarding process mining methodologies and process mining alternative solutions in the field of ITSM were discussed. The *Second Round Interview* was focused on achieving the data saturation point by examining and inquiring about the PM4CSI V0.2. The final goal of expert interviews is to have a clear process mining framework that can be used in the context of continual process improvements. Furthermore, the data analysis collected during the 19 interviews across two rounds followed a grounded theory approach. Section D.1.3 from Appendix D presents the specific considerations that were taken for conducting and reporting the grounded theory as recommended by Stol et al. [85]. Figure 5.2 illustrates the process followed during the framework refinement expert interviews. *Appendix D presents an overview of the expert interview process, including the steps taken during the pre-interview process, interview protocol, and an overview of the grounded theory approach taken for data analysis.*

5.1.2 Interview Participants

As introduced in section 5.1.1, at least twelve interviews must be kept as a target threshold to ensure sufficient data saturation. Thirteen experts chosen are from multiple organizations, six countries across the globe, and had varied roles, ensuring the generalizability of the data collected through these interviews. The information on the role, current company, location, gender, and source of connection of the experts involved in the framework refinement interviews can be seen in Table A.2 available in section A.2 of Appendix A. A total of 19 interviews were spread over two rounds. All the experts were interviewed in individual online sessions, and the interview details of each interview for both rounds of interviews can be seen in Table 5.1.

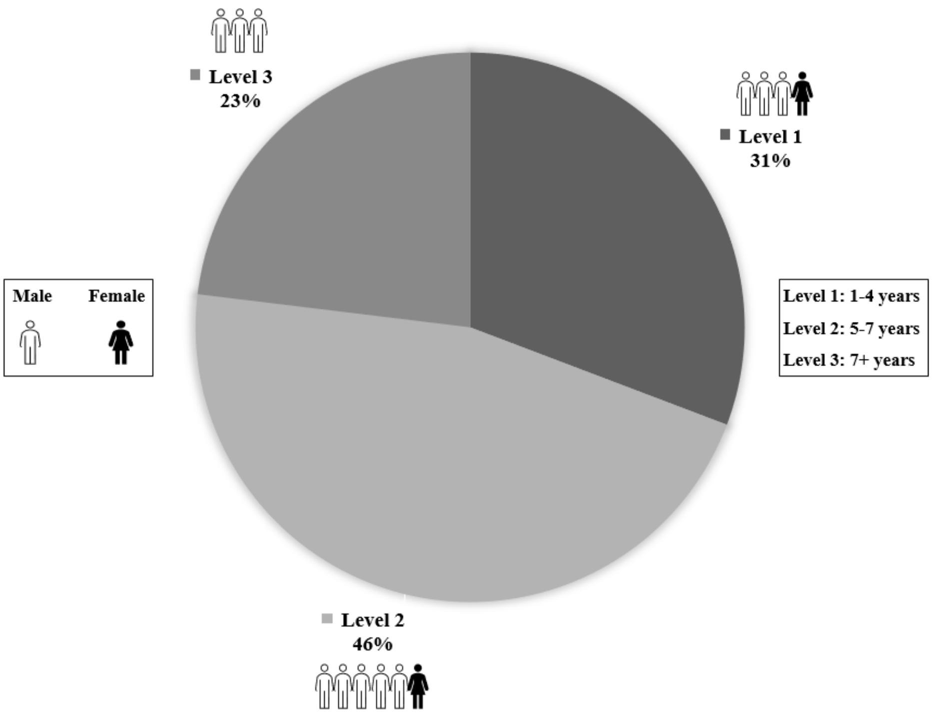

Figure 5.3: Proportion of participants' experience level in the field of process mining and/or service process improvements

The experience in Table 5.1 refers to the interviewee's experience in process mining and/or service process improvements. Due to the novelty of the field of process mining and the fact that the IEEE Task Force for Process Mining was established only in 2009, the interview sample was meticulously selected based on profiles which had at least three years of experience

First Round Interview				
Expert	**Role**	**Experience**	**Date**	**Duration**
E01	Process Mining Manager	4	17-10-2022	00:46:56
E02	Senior Process Mining Consultant	9	13-10-2022	01:00:34
E03	Senior Process Mining Consultant	3	14-10-2022	00:59:36
E04	Global Business Process Transformation Leader	5	17-10-2022	01:02:11
E05	Process Mining Consultant	5	13-10-2022	00:59:17
E06	Process Mining Manager	6	17-10-2022	01:08:18
E07	Senior Product Lead	8	10-10-2022	00:45:27
E08	Process Mining Excellence Center Consultant	3	10-10-2022	00:56:58
E09	Data Analytics Associate Director	5	11-10-2022	45:03:25
Second Round Interview				
Expert	**Role**	**Experience**	**Date**	**Duration**
E02	Senior Process Mining Consultant	4	03-11-2022	00:48:25
E03	Senior Process Mining Consultant	3	27-10-2022	00:53:55
E05	Process Mining Consultant	5	27-10-2022	00:57:26
E06	Process Mining Manager	6	31-10-2022	00:45:28
E08	Process Mining Excellence Center Consultant	3	28-10-2022	00:39:24
E09	Data Analytics Associate Director	5	26-10-2022	00:32:24
E10	Senior Process Mining Software Development Engineer	3	28-10-2022	01:11:34
E11	Director Continual Service Improvement	7	27-10-2022	00:55:50
E12	Digital Transformation Technologist	10	27-10-2022	58:31:19
E13	Process Mining Center of Excellence Manager	6	01-11-2022	00:58:47

Table 5.1: Interview Participants' Details

working on projects related to process mining and/or service process improvements. Figure 5.3 illustrates the proportion of experience level of the participants involved in both rounds of framework refinement interviews'. Based on the years of experience specific to fields of research's interest, it has been categorized as follows: *Level 1*: 1-4 years, *Level 2*: 5-7 years; *Level 3*: 7+ years.

5.1.3 Data Collection

Each round of framework refinement interviews was spread across two weeks and around six working days. Each interview was guided by the interview protocol as shown in section D.1.2 of Appendix D. The interviews were conducted in an online setting using the Microsoft Teams application, and with the permission of the interviewees, the meeting minutes were recorded for future transcription. Simultaneously, the minutes were also recorded in the Otter.ai web application. Each interviewee has been introduced to the research assignment and objectives for a clear understanding of the research context. The researcher also had follow-up and prompt questions to build a natural flow of conversation. However, the interview protocol was a practical guide to not miss out on any information required from the experts.

Infographics, as shown in figure D.1 and figure D.2, were presented to the experts using the Microsoft PowerPoint application, which enabled an interactive session with visual cues and highly improved the clarity of the conversation throughout the meeting moments. At the end of every interview, it was ensured that the meeting recordings were saved and documents collected were categorized into a folder in the researcher's OneDrive repository. Cloud storage of data collected, such as interview recordings, and documents, ensure backup files are available in case of data loss due to technical issues. After the first two interviews during the First Round Interview, it was found that while using the headphone gadget as the interviewer's mode of microphone, the Otter.ai web application failed to capture the interviewee's response.

Fortunately, it was identified during the earlier stages of the interview and rectified during the rest of the interview process. Using the recordings saved in the Microsoft Team application, the first two interviews of the First Round Interview were loaded into the Otter.ai application for automatic transcription of the meeting minutes.

5.1.4 Data Analysis

This section discusses the two-phase analysis performed on the data collected from meetings of the interviews. The first phase involves transcription of the interviews, followed by performing coding steps using Straussian grounded theory concepts [86] for obtaining First Round Interview results and data analysis of transcripts from the Second Round Interviews.

Transcripts of Expert Interviews

The first phase of data analysis is producing expert interview transcripts. The interview with experts was held online using Microsoft Teams, and the recorded meeting minutes were transcribed using the Otter.ai tool. The transcribed minutes were immediately re-read, reviewed, and corrected to check the transcripts for accuracy and eliminate the errors of machine-automated transcriptions. The transcription process of both rounds of interviews resulted in approximately 13 pages per interview. The transcripts have been anonymized and had approval from the interviewees. Then, the transcripts were used for further analysis. The final results from both rounds of framework refinement interviews can be seen in section 5.2 and 5.3, respectively. However, each of the transcripts from the 19 interviews is not attached to this report but can be requested separately.

First Round Interview Transcript Analysis

This research used grounded theory to develop new theories and concepts based on the interview transcripts of the First Round Interview. The data collection process is known as theoretical sampling [86]. Grounded theory has been chosen specifically to synthesize data that would fill the gaps in the knowledge available in the academic literature of process mining applications in the improvement of processes in ITSM sphere. The transcripts have been quoted under codes that corresponded with the interview protocol (refer section D.1.2). Quoting the data collected into respective codes served to aggregate all data corresponding to answering the relevant research questions. Straussian grounded theory approach [86] was followed in the analysis of qualitative data collected during the interview. Open coding, axial coding and selective coding are steps in the Straussian grounded theory method of analyzing qualitative data. A detailed description of the qualitative grounded theory data analysis approach taken during this research is presented in Section D.1.3 of Appendix D

Every interview transcript was analyzed at the earliest to keep the memory of essential takeaways like participants' gestures and emotions. All three coding steps were conducted iteratively to build a new theory in our collected transcripts. The iterations only stopped when there were no further modifications and the theory had well-thought-out propositions. Nvivo software was used to conduct each loop of open-axial-selective coding. The coding method ensured that codes for each category were identified and collated accordingly. The codes were revisited during the analysis of every single transcript. New codes were added to data that did not fit the category of codes created during the analysis of earlier transcripts. The relevant quotes for each category can be seen in Table D.1 in section D.1.3 of Appendix D. The coding percentage contributed by the participants in each category is shown in Figure 5.4

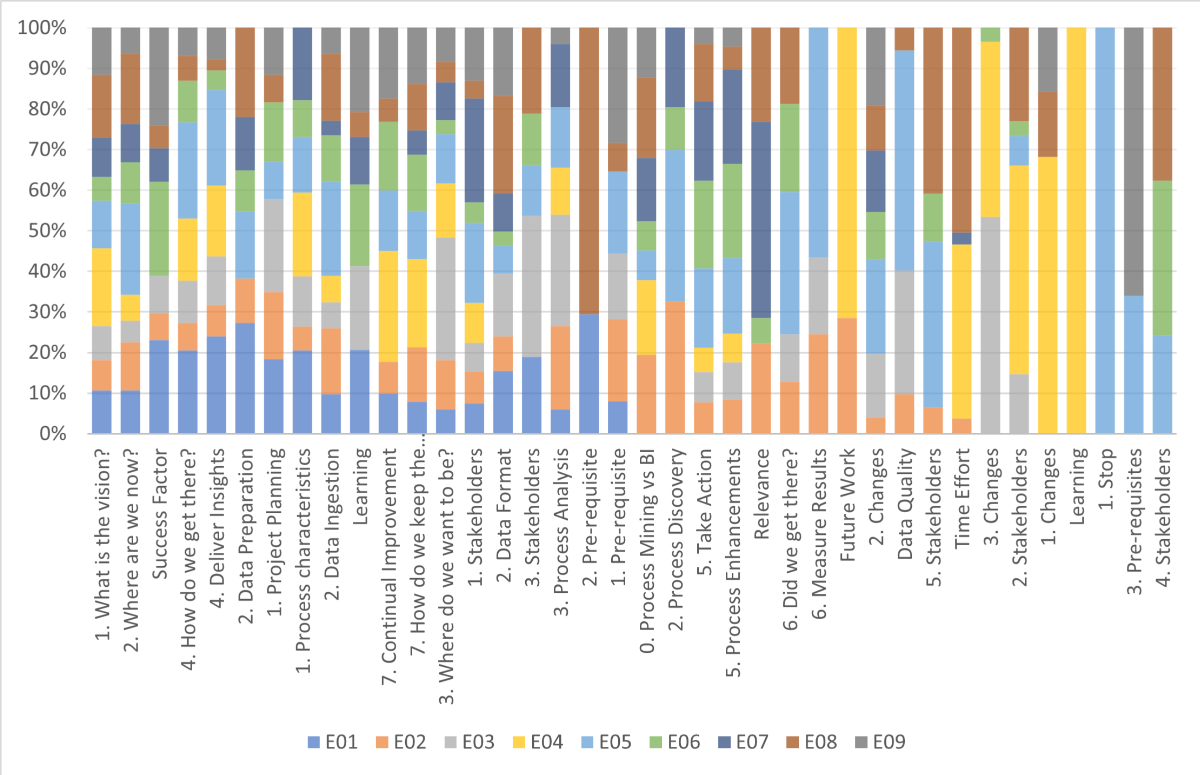

Figure 5.4: Visualization of the coding percentage of each category contributed by the nine experts in First Round Interview

Second Round Interview Transcript Analysis

The purpose of the Second Round Interview was to refine the PM4CSI V0.2 to attain theoretical saturation. The refined interview transcripts were analyzed immediately as mostly the participants agreed with the PM4CSI V0.2. Only minimal modifications were suggested in each phase of the Process Mining Approach aligned with ITIL Continual Improvement Model. Hence, the data were analyzed after almost every interview in the Second Round Interview. Thus, for the Second Round Interview, the PM4CSI V0.2 was updated after every interview or two. The quotes from interview transcripts were reviewed by two peers at the end of the Second Round of Interviews to avoid researcher bias in data analysis. The feedback from the peers was positive and confirmed that the analysis was valid.

5.1.5 Interview Data Validity

It is a great challenge to validate the data from qualitative interviews as it cannot be measured using a mathematical formula. Several reliability checks were constantly employed to mitigate the subjectivity in the analysis of transcripts and the coding process. Firstly, the codes, categories, and descriptions have been carefully reviewed by employing peers. The choice for peer review is because the peer can critically evaluate the process of interpretation without being an expert on the fields of this research. Meetings were scheduled with the peers to discuss the decision made while corroborating the evidence from the data interpretation. Moreover, most of the identified steps in the process mining approach suggested integrated with the findings from the literature review, which supported and ensured the researcher's findings were legitimate. Validating the results from the qualitative expert interviews is crucial since it reduces the risk of decisions based on the interview data. Hence, the study has been subjected to validation, presented in Chapter 7.

5.2 First Round Interview Results

The PM4CSI V0.2 was designed and developed based on the results derived from First Round Interview data analysis. The data has been synthesized in the same order as the PM4CSI V0.1, which will provide the researcher and the readers a precise clarity of what happens in every phase and what modifications are required to the PM4CSI framework.

1. What is the vision?

The first phase of ITIL Continual Improvement initiative is generally comprehensive as failing to plan an improvement initiative is planning to fail. Project planning allows for making better decisions and guides through the different stages of the improvement project. Firstly, it is essential to notice that process mining projects follow a value-driven approach. One guiding principle of ITIL during the first phase is also to *Focus on Value*. Hence, the first and foremost action is to define the *North Star*, i.e. the significant value the improvement project can bring to the stakeholders. For defining the North Star of the improvement project, it is essential to define the scope of the improvement projects and have a high-level business case in place. Organizations constantly analyze industry benchmarks and/or industry best practices for seeking performance-level indicators of their business processes, such as striving to stay in the top quartile to have a competitive advantage. Such industry benchmark analysis would allow for defining the vision of the improvement project. Also, it is beneficial to have a baseline metric for our future analysis. These metrics and problem areas will help formulate hypotheses and research questions.

When a sick person visits the emergency room, they are asked about the cause of their visit to understand the problem and pain areas. Suppose the person suffers from a headache. Then, the doctor will get an X-ray scan of the head area to analyze it more profoundly into a particular area. The X-ray allows the doctor to analyze the root cause and, in some cases, identify unexplored problem areas. Here, the X-ray is analogous to process mining [33]. Hence, it is essential to identify the problem areas and define the scope and vision of the improvement project. Then, a high-level business plan should be devised to see if a process mining tool can precisely analyze the root cause of the identified problems.

A high-level business plan provides an over-arching goal for the improvement initiative. All the stakeholders must be committed and understand that the improvement project should be a value-driven process. It is essential to strategically align the vision of the improvement project with the organizational goals. Once the project scope is defined and a high-level business plan has been developed, checking the feasibility of the process and availability of minimal requirements event data takes place. To check the process's feasibility, it is essential to understand the process and check if data associated with it is being tracked in the organizational information systems. One of the interviewees mentioned performing the feasibility check of the process to be optimized in a project pre-planning phase. Such pre-planning would expose whether the organization or department wishing to pursue process mining projects needs more data and people to implement a process mining project.

At this point of the planning phase, the focus is on accessing all the process-related data relevant and mandated for the analysis of the improvement initiative. Five of nine interview participants mentioned the importance of analyzing the underlying quality of data from the planning phase, as it helps achieve the project's goal and reduces reiteration to the planning phase in the later stage. In the worst-case scenario, performing process analysis with poor-quality data will derive inaccurate insights, which does not generate value from the improvement initiative. With

General Data Protection Regulation (GDPR), handling the information security and regulations of accessing the data and the associated data source systems is crucial. The data privacy team must align on what is required to be anonymized or subject to a confidentiality clause. Also, a session for the process mining technical expert to understand the operational aspect of the process in question takes place at this phase.

The success of process mining depends on the 3P's - *People, Purpose,* and *Process instances* as shown in Figure 3.13. Alongside the data aspect, stakeholder management also happens during the project planning phase. The success of the improvement initiative depends heavily on onboarding the human resources who are committed to the initiative. The required stakeholders involved in *What is the vision?* phase includes the following:

- Project Manager - one who keeps up with the overarching project goal in the scope, determines what needs to be achieved, and is responsible for the process mining project.
- Process users - people who are working daily to check if all the important activities are tracked in the PAIS as process instances.
- Subject Matter Expert - one who understands the execution of the process from an operational perspective and has knowledge of the aspects of data quality
- Business Owner - one who has the authority to sign off the action plans from an operational perspective.
- Solution Architect - one who knows the customization of the organization's underlying data and IT architecture and helps to gather data that would validate the expected data model for process analysis.
- IT Expert - one who provides access to the data and data source systems and understands the underlying quality of the data.
- Decision Maker - the department's leadership who gives a picture of the expected business outcome, i.e. C-suite executives in an organization. The decision-maker must have trust and motivation for the success of the project.
- Process mining technical Expert - to understand the project objective based on which further process analysis can be performed.

The project planning phase is decommissioned for the following reasons:

- If the decision maker or sponsor is not interested in the project.
- Feasibility check of process characteristics fails.
- If the process mining improvement initiative is more expensive than the expected value generation, i.e. if the process mining improvement project leads to a negative return on investment.

The Ground technical prerequisite for a process mining project is to need the data in event logs. All the interviewees agreed with the minimal data requirements - Case ID, activity and timestamp. These three data attributes always hold as a prerequisite; with them, it is feasible to have a process mining aspect to an improvement project. Also, the literature recommends having an a-priori business model as a Business Process Modelling Notation (BPMN). Interviewees mentioned that having an a-priori business model is good but optional. It could either be in a BPMN or any notation with a certain level of accuracy. Such a model could help the process analyst translate and understand the service process as a process owner or data expert does. Additionally, when prompted with a question about the minimal number of activity states in a process, all the interviewees mentioned that, in practice, the number of activities is primarily subjective in real-world processes. Hence, it is not an obligated prerequisite measure for process mining applications. It is also essential to collect the list of KPIs based on the overarching objective of the improvement initiative.

2. Where are we now?

Interviewees gave unanimous recommendations for modifications in the PM4CSI V0.1. The modifications suggested were to include the data validation phase before process analysis and design the process discovery and process analysis together as they were practically ongoing phases. Besides the modification, the following are the synthesized data for the second phase of ITIL Continual Improvement Model.

- **Data Ingestion:**
  Data ingestion usually happens in two ways. When the company is mature with process mining and has process mining integrated IT architecture, then data connection can be established and perform scripting to analyze the data connection. If the company does not have a meaningful process mining provider and opts for a one-time service, then the data is extracted and ingested into the tool again. The data is usually connected to the process mining tool directly. Raw data is ingested into the tool, and the data preparation phase occurs in the process mining tool. Since data is most directly connected, the data format is no longer a hard criterion for the application of process mining. Direct connection to information systems allows no mistakes in raw data and real-time dynamic data analysis. The interviewees preferred working with the live connection of data with the advent of process mining tools in the market and their capabilities. Working with CSV or other flat files is not recommended unless it is the case. The format for the second way of data ingestion, i.e., file uploads highly, depends on the process mining tool. Most of the tools work with CSV, XES format or any structured data that can be configured with SQL language. Technically, the workaround is available for transforming unstructured data, but it requires much human effort. For example, contract data can be read through Optical Character Recognition (OCR) and make an effort to extract and structure such data. Data manipulation can be made using python or standard scripts for processes to attain a compatible file format. Eventually, the data should be in the compatible format as an event log to do further analysis.
- **Data preparation:**
  Firstly, the event data extracted are pre-processed, which involves data cleaning and transformation. The event data is subjected to SQL scripting to produce event logs for process mining analysis. It is essential to create fact and dimension tables following a star schema. The attributes are mapped to the case level and event level. Hence, data mapping is performed on the event log. Following the data mapping, it is essential to build models and validate them. It is recommended to have attributes related to categories of ITSM operations to avoid processes with a different workflow.
- **Process Discovery:**
  As extensive as this phase is in academia, with lots of work going to developing the algorithms for process discovery, in practice, with the process mining market tools, this is a minimum phase. Once the event log has been prepared that is compatible and effective for process analysis, the first step is to discover the process related to the event log as a directed-flow graph. A process digital twin is discovered in this phase. Data quality is also validated in this phase to have relevant and efficient insights. Once the process is explored, a first glimpse of process variants and possible PPIs can be discovered.
- Required stakeholders:
  - Subject Matter Expert - to validate process flow and data

  - Solution Architect - to validate the data model
  - IT Expert - one who provides access to the data and data source systems and understands the underlying quality of the data.
  - Data Engineer - to perform the ETL (Extract, Transform, Load) activities
  - Process Mining Technical Expert - To perform further process analysis.

3. Where do we want to be?

As mentioned in the previous phase, process discovery and analysis are generally ongoing with multiple iterations. The process analysis phase is exploratory. First, in the process analysis phase, a clear definition of KPIs and PPIs is identified. These indicators are the metrics for improvement. Process mining enables visibility of pandora's box of processes. The hypothesis formulated in the first phase, *What is the vision?*, may be confirmed or completely falsified by analyzing the process. In a few cases, the vision of the improvement project needs to be redefined to have tension between today and future process execution. It is also important to check if the process mining analysis aligns with the insights found using other Business Intelligence techniques if any are available. A combination of different types of analysis based on the process mining capabilities, as mentioned in section 3.1.5, has been performed in the process analysis phase. Conformance checking is one of the popular selling points for process mining technology. However, the interviewees have unanimously reported that many organizations are not interested in conformance checking as the value generated from it is very low. After analyzing the anomalies and patterns in the process, a first glimpse of what value can be realized will be realized by identifying areas of issues or optimization. With the results of analysis, Root Cause Analysis (RCA) is conducted to get an answer to the question *"Why?"* . RCA provides a profound understanding of how we can optimize the process. The following stakeholders are involved in this phase:

- Subject Matter Expert - to validate process flow and data
- Process Mining Technical Expert - to perform analysis based on process mining capabilities
- Value Architect - to oversee the whole process and drive measurable business value.

4. How do we get there?

Generally, the insights from process mining analysis could be an organizational change or process change. In this step, ideas for process optimization will be provided. The process analyst and value architect suggested that changes should be based on value realization. The most significant bottleneck is the duration it takes to wait on the stakeholder who can validate the insights delivered by the process mining technical expert and value architect. Based on the validated insights, actions for improvement plans should be formulated. It is best to align the identified use cases with the strategic objectives found during the *What is the vision?* phase. The interventions suggested as improvement use cases should be prioritized based on the value and effort required. Then, develop the business case for each use case. The improvement plans are executed only when the sponsor realigns with the business case and signs off the budget required to implement the improvement. The following stakeholders are involved in this phase:

- Project Manager - one who keeps up with the overarching project goal in the scope, determines what needs to be achieved, and is responsible for the process mining project.
- Process users - people who are working daily to check if all the important activities are tracked in the PAIS as process instances.
- Subject Matter Expert - one who knows the business aspect and understands the execution of the process from an operational perspective

- IT Expert - one who is familiar with IT aspects of the processes and the systems supporting the process
- Decision Maker - the leadership of the department who gives a picture of the expected business outcome, i.e. the C-suite executives in an organization. The decision-maker must have trust and motivation for the success of the project.
- Process mining technical Expert - to understand the project objective based on which further process analysis can be performed.

5. Take action

Take action phase is the value creation phase, where process improvements are initiated. Process improvements are the primary motivation and success for any process mining project. People believe that desired results can be achieved, which is a difficult step. The actual implementation of modifications in the process follows a specific project methodology, and it is essential to gather requirements for the execution of improvements. As the process is being changed, the world is constantly evolving, and the regulations associated with the process, people, and technology keep changing. A continuous feed of opportunities and items needs to be managed and delivered accordingly. The most typical enhancements in ITSM operations involve change management or automation. Such process enhancements will enable operational excellence based on facts delivered by insights from process mining analysis. The following stakeholders are involved in this phase:

- Project Manager - one who keeps up with the overarching project goal in the scope, determines what needs to be achieved, and is responsible for the process mining project.
- IT Data Source System Engineer- one who is familiar with the IT aspect of the processes and the systems supporting the processes.
- Value architect is one who frames what to do to obtain value from the enhancements.
- Process Users – who work with the process day-to-day
- Change Manager - one from the Change Advisory Board (CAB) who is responsible for the approval of change requests.
- Workflow developer - one who implements the changes to the workflow

6. Did we get there?

With live data ingested into the tool regularly, different approaches to measurements can be taken based on the type of use cases. Process enhancement is usually measured by tracking the KPIs in programmatic software. It is good not only to look at lower level KPIs. Global process owners often look up to high-level KPIs to measure the value of their business. All the stakeholders of the improvement project will be needed during this phase.

7. Support Continual Improvement

Process mining provides visibility to the actual execution of the process and showcases the inefficiencies of the process. It is essential to not look at a process as a silo and try to incorporate as many departments as holistically as possible. Process mining should be aimed not as a one-time project for a particular process in a silo but more like a general approach to achieving process optimization. Thus, a continuous flow of use cases can be identified for optimization. One of the interviewees suggested providing customized dashboards with process mining tools as action boards for different roles involved in the improved process and incorporating them in their quarterly business meetings. Sometimes, the inefficiencies in the process are caused by insufficient data, and it is best to improve the process of tracking relevant data. Process mining is a crucial enabler for fueling continuous improvement culture

[33]. There is a difference between 'continuous' and 'continual' that should be considered when process mining is applied in ITSM sphere. *Continuous* refers to something that happens without interruptions over a while. In contrast, *continual* refers to when an event happens at regular frequencies. While process mining enables continuous improvement initiatives, ITSM requires continual improvement. The process mining market tools such as Celonis, UiPath, and others can improve the organization's processes operationally. These tools allow us to improve the workflow, for instance, by setting up alert systems or automated emails to process users.

General findings

- **Process Mining Vs other Business Intelligence solutions:**
  Data-driven process analysis is not a new terminology, as an analyzing process with data has been in practice for over a decade. However, with the help of process mining, deriving the insights and decision-making process is expeditious. It offers quicker governance and decisions for process continuity and improvements. With process mining, one can perform root cause analysis to explore the "Why?" of the identified pain points in our processes that business intelligence tools cannot achieve. Within ITSM industry, process mining can help reduce multi-hops, reduce costs, identify areas best suited for *shift left*, meet SLA requirements and increase transparency, which in turn increases customer satisfaction (measured using Net Promoter Score).
- **Relevance:**
  The experts have found it interviewed that there needs to be more information found in the literature with the advent of modern commercial process mining applications by leading vendors in the market.
- **Success factors for process mining projects:**
  The critical success factors for a process mining project are the executive sponsor, committed and highly qualified team, and business knowledge about the processes in focus. The sponsors' tasks that cannot be delegated include the following: *establish and communicate the business case for action, participate in goal setting, allocate resources; Concentrate their energy on their direct reports by stating and continuing cascading sponsorship, align and apply the reward and recognition systems for their direct reports; and monitor progress constantly*. Besides governance and impact, technology and data also play an essential role in the success of a process mining project.
- **Time taken for each of the phases:**
  The time taken for each phase in a process improvement project using process mining has no saturated results through the interviews. The data collected from different experts are as follows *(see Table A.2 for more details about the experts mentioned below)*:
  E09 and E04: Assuming that the three Ps (People, Purpose, and Process instances) are ready and committed to the project, it takes 12-15 weeks from *What is the vision?* until *How do we get there?* phase. The remaining three phases' time depends on the previous phase's findings.
  E08: Relatively, based on the PM4CSI V0.1, the time is distributed as: 10% for *What is the vision?* phase, 20% for *Where are we now?* phase, 10% for *Where do we want to be?* phase, 20% for *How do we get there?*, 20% for *Take action*, and rest 20% for measuring results and supporting continual improvement. Expert E08 added that with a predetermined extractor and application from Celonis, for an improvement project to optimize one specific process, the entire cycle of ITIL continual improvement can be completed in 1-2 months.
  E07: It is hard to estimate how much time is required for each phase. The reason is that creating an event log can range between a couple of hours to a few months, depending on the system's complexity. However, for ITSM operations, it would be relatively simple as the ticket ID will have a one-to-one relationship.

5.2.1 Design and Development PM4CSI V0.2

The analysis of the interview results presented above led to redesigning the PM4CSI v0.1, as the data contributed by scientific literature varied vastly with the approach taken in the practical application of the process mining techniques with real-time industry data. Consequently, an intermediate version of the framework referred to as PM4CSI V0.2 has been created. In PM4CSI V0.2, the phases of process mining approaches have been modified by adding, merging, or eliminating phases from PM4CSI V0.1, based on the information collected from domain experts. Figure 5.5 illustrates the high-level abstract of the PM4CSI V0.2, and the activities to be taken during each step with required inputs, stakeholders, and expected outcomes can be seen in Figure D.2 from Appendix D.

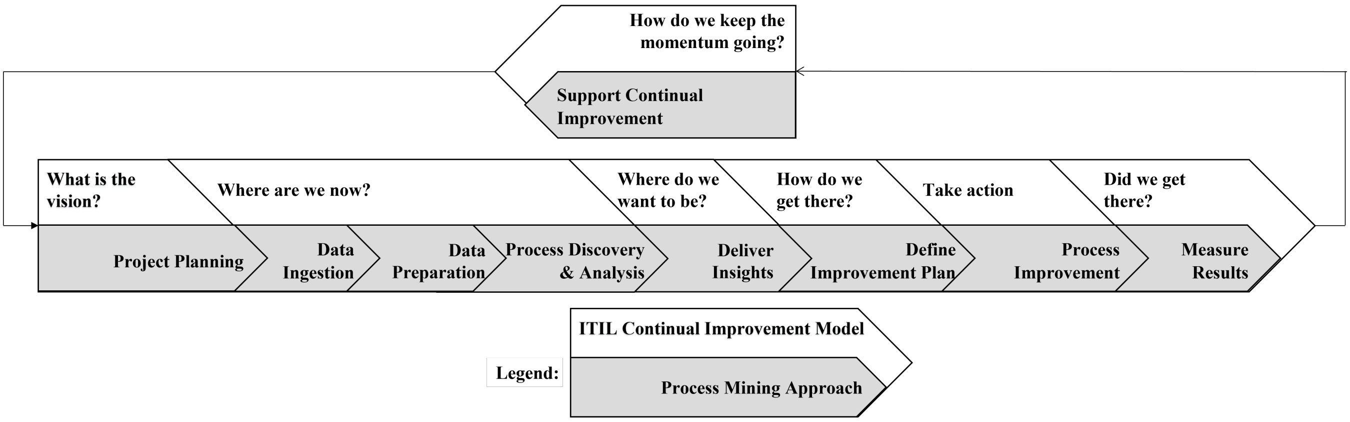

Figure 5.5: PM4CSI V0.2

5.3 Second Round Interview Results

The primary purpose of the Second Round Interviews was to achieve data saturation, ensuring sufficient data to make the necessary conclusions and that any additional data gathering would not result in valuable insights. The refined version of PM4CSI was designed and developed based on the results derived from the Second Round Interview data analysis. The data is synthesized in the same order as the previous versions.

1. What is the vision?

The tasks were mixed up from a sequential perspective. *Analyze industry benchmark* can be a part of defining the vision. The tasks in the planning phase can be considered in two parts. The first part of planning covers the tasks such as identifying problem areas, identifying stakeholders, analysing industry benchmarks, defining the scope and vision, formulating research questions for analysis, developing the high-level business case and understanding the process. Followed by these sub-activities, the second part focuses on data such as identification of data source systems, checking for data availability and handling the data regulations. The scope and vision should match the business's overall objective and have a strategic alignment. One of the essential tasks to be added is *setting up milestones for the project* which involves meetings and project planning for the milestones of the process mining project.

2. Where are we now?

Data quality is a process that happens at every step, right from the planning phase to the process analysis phase. It has been brought to our attention that it is optional to perform all the analysis as mentioned in figure D.2. Dashboards should be built only based on the vision of the improvement project and focusing on the value. It has been suggested to combine the task, *describe and map event data*, with the task, *understanding the data*. Also, getting access to correct data ensures that data is only ingested, not more than required. Failing to do so will significantly increase the complexity of the process models. Process discovery allows the identification of possible execution gaps from the digital twin of the process created by the process mining tools. Interviewees recommended that building a dashboard and root cause analysis is an iterative process.

3. Where do we want to be?

While delivering insights, it is vital to build a customized dashboard based on the roles that the insights are presented. The fact-based insights delivered during this phase will act as baseline metrics which will help set the target and also help in the value assessment of improved outcomes. Involving the SMEs, IT system engineers and developers while formulating the list of potential improvement areas will make the list of optimization areas effective and act as the first check of feasibility for implementation of proposed improvement ideas.

4. How do we get there?

The interviewees complemented the tasks aligned with this phase of the PM4CSI V0.2. In practice, value-driven prioritization of the use cases is facilitated by the Impact-Effort matrix or a cost-benefit analysis. The use cases that are easier to realize value with less effort and cost are prioritized and pushed for the following action phase.

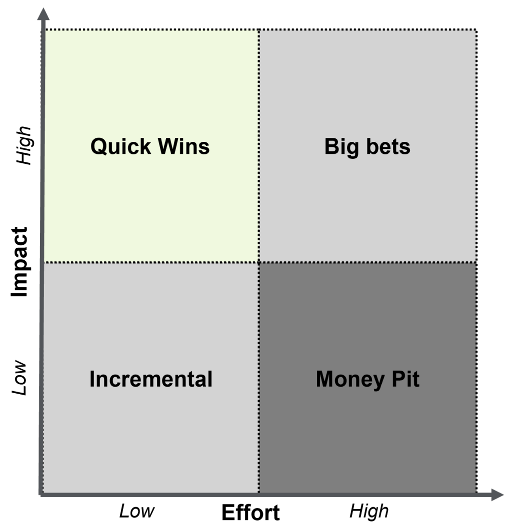

Figure 5.6: Impact/Effort matrix for prioritization of improvement use cases

5. Take action

The selection of use cases and improvement plans can be clubbed together as a single task marking the kick-off for the improvement project. Five interviewees broached the practicality of process mining insights not necessarily leading to process redesign. Sometimes, it is implementing technical training sessions for the service support team that helps to score better for First Call Resolution (FCR), a customer service metric.

6. Did we get there?

The *Measure results* phase starts with process improvements and process-oriented data for the changed processes. It is crucial to provide training and enablement for the involved stakeholders on how to continue using the process mining tool and dashboards for continual analysis of the process in focus. It has been recommended to rephrase the *Deliver Insights* task to *Deliver value* task as the findings from measuring the results are the value delivered by the process mining project.

7. How do we keep the momentum going?

The insights generated on this phase of the PM4CSI V0.2 remain the same as the results from First Round Interview.

5.3.1 Design and Development Refined PM4CSI

All the experts in the Second Round Interviews contributed comments that helped the researcher achieve data saturation. The high-level abstract of the PM4CSI and other components, such as the activities, inputs and stakeholders, had minimal modification, such as renaming terms and order. To summarize, PM4CSI shows an ITSM practitioner where process mining techniques can be used to complement the existing techniques in the ITIL Continual Improvement Model. The refined PM4CSI framework presents a flow throughout the steps to be taken within each phase. Furthermore, it is possible to iterate back to any step, but such edges are neglected in the PM4CSI framework to ensure readability. PM4CSI V1.0 has been designed based on the results from the refinement interviews. The next chapter explains the activities and requirements within each step of the refined version of PM4CSI, i.e. PM4CSI V1.0, in a detailed manner.

5.4 Summary

- Considering the novelty of the research area, i.e. application of process mining to assess and improve ITSM sector, the identification of activities performed in process mining initiatives proved ambiguous, insufficient, and lacked complete guidance on how to carry an end-to-end process mining project in ITSM sphere. Thus, the data on the activities performed in a ITSM improvement initiative using process mining technology were qualitatively collected through interviews.
- Participants were chosen based on diverse expertise, experiences, and organizations for semi-structured framework refinement interviews. Table 5.1 presents the details of the interviewees.
- Two rounds of interviews were planned with thirteen experts to ensure the interview validity by achieving saturation on the collected data. The interview protocol has been designed to ensure a similar approach and collection of data from all the experts.
- The meeting minutes were transcribed for analysis using the Straussian grounded theory approach. Appendix D presents an overview of the expert interview process, including the steps taken during the pre-interview process, the interview protocol, and an overview of the grounded theory approach taken for data analysis.
- The results of the first round of interviews led to the design of an intermediate version of the framework, PM4CSI V0.2. In PM4CSI V0.2, the phases of process mining approaches have been modified based on the information collected from domain experts.
- Second round of framework refinement interviews was conducted to attain data saturation to ensure that any additional data gathering would not result in insights that would be of value. Consequently, PM4CSI V1.0 were designed and developed, which will be discussed in the following chapter.

Chapter 6

Refined Framework

This chapter presents the refined version of the framework, PM4CSI V1.0, resulting from the literature study and saturated data collected and analyzed from two series of expert interviews. PM4CSI V1.0 framework is developed as a three part framework which consists of a high-level graphical abstract, a graphical detailed overview of the framework and detailed explanation of PM4CSI phases. The detailed explanation covers level-wise explanatory text in the form of an activity flow diagram and tables. Additionally, a table depicting the stakeholders required, responsible roles, the input, the activities and the output of each phase of PM4CSI. Firstly, section 6.1 presents the overview of PM4CSI V1.0. Section 6.2 elaborates on the contextual information of PM4CSI V1.0 and discusses the activities that are required at each PM4CSI V1.0 phase. *It should also be noted that beyond this point of the report, if the version has not been mentioned explicitly as a suffix to the framework, it refers to the refined version - PM4CSI V1.0.*

6.1 Elements of PM4CSI V1.0

A graphical representation of the abstract level of PM4CSI V1.0 is shown in Figure 6.1. The starting phase of PM4CSI has been denoted with a star symbol. The legend is presented on the right side for the roles responsible for each of the phase and for denoting which phase involves process mining techniques or require process mining tool support. The circles represent the phases that should be taken to perform continual service improvements by leveraging process mining techniques. The main blocks are based on the process mining approach designed from scientific literature and refined by field experts as described in chapters 4 and 5. The goal is to facilitate the application of process mining to assess and improve ITSM process effectively. Hence, the steps of the PM4CSI have been aligned with the phases of the ITSM's proven framework - ITIL Continual Improvement Model (*Requirement: Relevance satisfied*). The PM4CSI consists of nine steps in the central flow: *Project Initiation, Data Ingestion, Data Preparation, Process Discovery and Analysis, Deliver Insights, Improvement Planning, Process Improvement, Measure Results, Support Continual Improvement.* The framework has a layer showing the critical stakeholder as the leading role responsible for each phase of the PM4CSI. Since some duties in each phase are better performed by a specific role than another, there is a particular lead role responsible for each phase. Although each stage is tied to a particular role, the tasks at each phase require a collaborative effort of members from all of these roles and utilizing the expertise provided by each of them.

Figure 6.2 represents the detailed overview of PM4CSI with all the activities taken at each

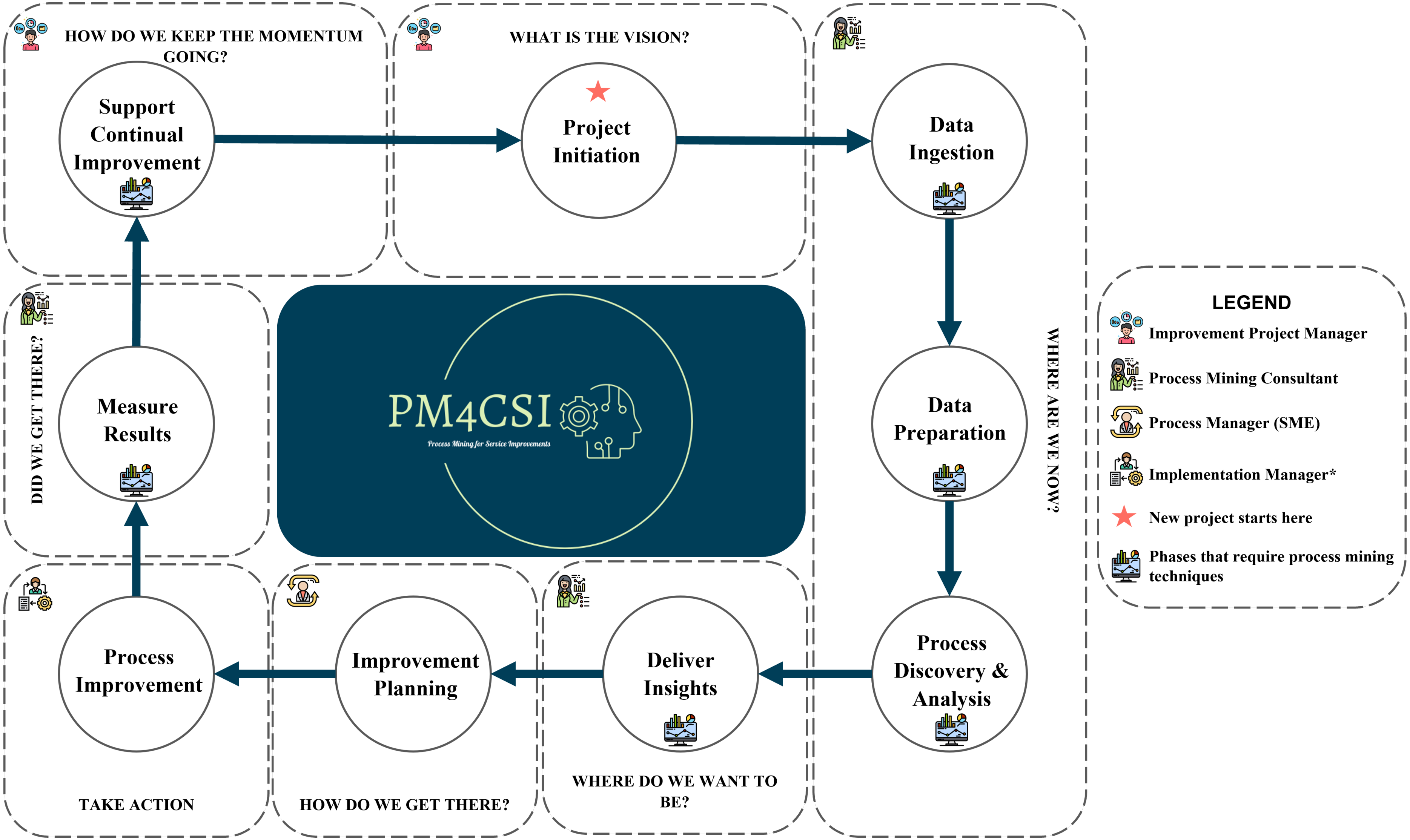

Figure 6.1: Process Mining for Continual Service Improvement - PM4CSI V1.0

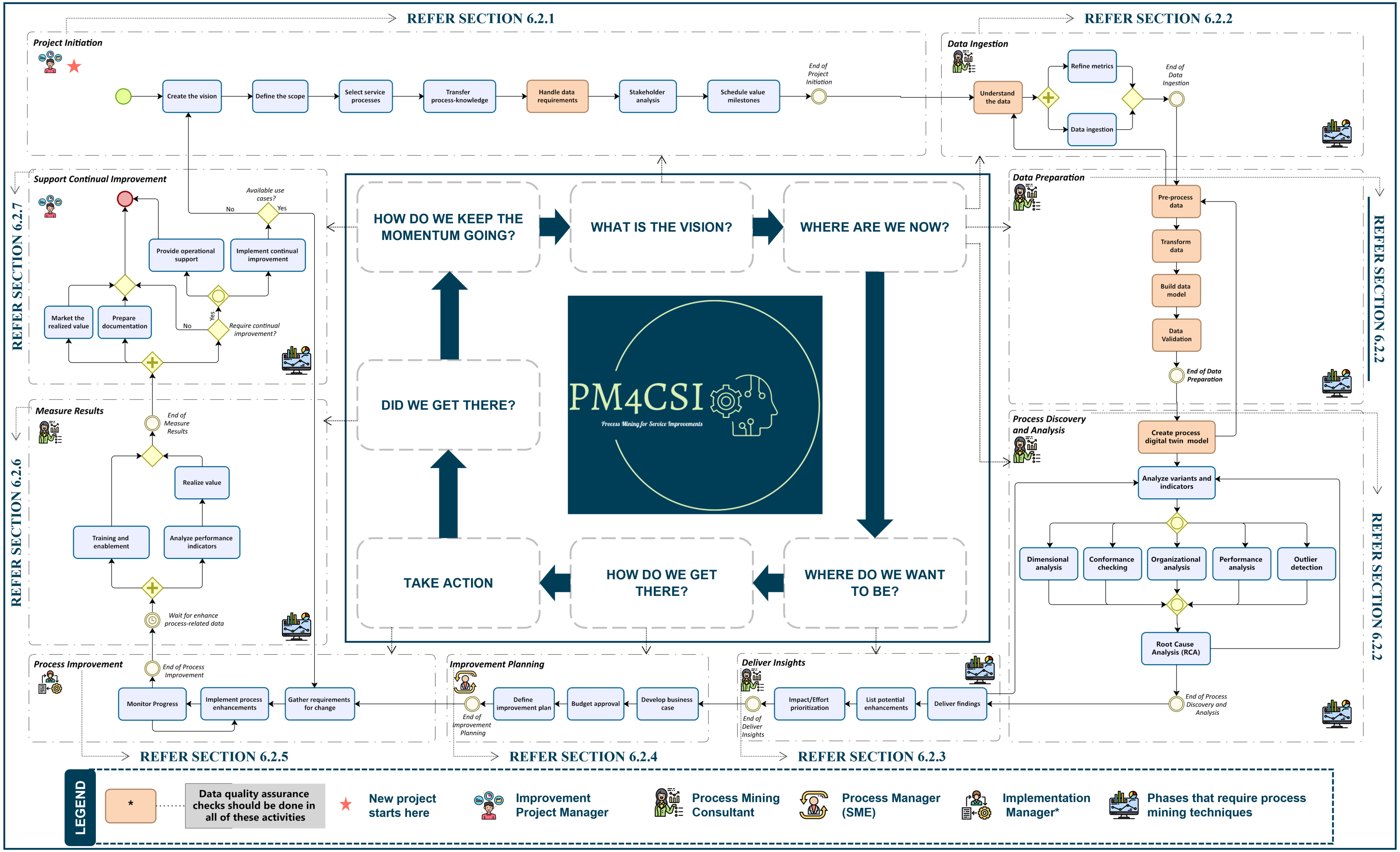

Figure 6.2: Detailed overview of PM4CSI V1.0 activities

main block shown in Figure 6.1. The detailed overview of the PM4CSI V1.0 shows the path taken through the improvement initiative with PM4CSI V1.0 and the necessary iteration flows. *Bizagi* tool was used to represent the detailed overview of PM4CSI V1.0 activities to represent the framework that is intuitive to business users and is also able to represent complex process semantics.

6.2 Detailed Explanation of PM4CSI V1.0

The previous section showcases the main flow and detailed overview of PM4CSI phases. This section defines attributes such as responsible roles, prerequisites, output and relevant activities that should be performed for each phase of the PM4CSI V1.0. Table 6.1 presents the characteristics such as prerequisites, required roles, activities, and output of conducting each activity in every phase of the PM4CSI V1.0. The roles represented in bold font are the stakeholders responsible and accountable for the corresponding PM4CSI phase. The roles and responsibilities of each of the stakeholders mentioned in Table 6.1 are as follows:

- ***Improvement project manager*** is responsible for managing improvements to ITSM process and IT services. ITIL refers to this role as Continual Service Improvement Manager [2]. During process mining improvement initiative, Improvement project manager is responsible for *Project Initiation* phase to ensure all the activities are accomplished during this phase. It is essential as the first phase sets up the commitment and objective for the rest of the project phases. Improvement Project Manager is also the key role responsible for *Project Intiation* and *Support Continual Improvement* phases of PM4CSI.
- ***Process owner*** is the person responsible for designing, sponsoring, and Continual Improvement of process and its metrics [2]. In case of a large project, the sponsoring will be taken care by the business owner. But considering ITSM process and from the point of ITIL's perspective, process owner is the only person who has authority to make changes in the process and manages the entire process improvement cycle to ensure performance effectiveness [2].
- ***Process manager*** is the subject matter expert who has the knowledge on the operational management of a process. Process manager is collaborated with the process mining consultant throughout the project
- ***Process users*** are individuals that complete the centre exercises of a procedure everyday.
- ***Master data owner*** has knowledge on the data architecture and data source systems. The data owner is responsible for identifying relevant data tables associated with the problem areas and assists process mining consultant wherever data support, extraction or connection is required.
- ***Process Mining Consultant*** is the key role responsible for most of PM4CSI phases such as *Data Ingestion, Data Preparation, Process Discovery and Analysis, Deliver Insights,* and *Measure Results*. The Process Mining Consultant is the technical expert responsible for conducting end-to-end process mining and process analysis to identify the bottlenecks and potential improvement areas in a data-driven way using the process mining tool. This role also needs to ensure that the insights are value-driven and align to the objective of the improvement project. Additionally, measuring results after process enhancements and supporting continual improvement is also the responsibility of process mining consultant.
- ***Implementation Manager*** is the key role responsible for implementing process improvements. Depending on the type of process enhancements, an Implementation Manager could be an organizational change manager or operational change manager or a service delivery manager.

Phase	Prerequisites	Roles	Activities	Output
Project Initiation	- Information regarding service operations to be optimized - Service processes to be implemented in a PAIS - Relevant data tracked in the associated information systems - Initial insights (optional) - a-priori business model (optional)	- **Improvement Project Manager** - Process owner - Process Manager (SME) - Process users (Optional) - Master Data Owner - Process Mining Consultant	- Create the vision - Define the project scope - Select service processes - Process-knowledge transfer - Handle data requirements - Stakeholder analysis - Schedule value milestones	- Strategically aligned vision and scope statements - Defined scope of the improvement project - Preliminary business case - List of processes, associated problems, KPIs, and business questions, and choice of process mining tool - List of data source information systems - Composed project teams and project milestones - List of hypothesis
Data Ingestion	- Strategically aligned vision and scope statements - List of data source information systems (Event) data tracked in PAIS - License for selected process mining tool	- **Process Mining Consultant** - Master Data Owner - Process Manager	- Understand the data - Refine Metrics - Data Ingestion	- Defined scope of data - Transfer process-related data knowledge - Event data files ingested into process mining tool
Data Preparation	- Ingested (event) data files - Data description	- **Process Mining Consultant** - Master Data Owner - Process Manager (SME) - Data Engineer (Optional)	- Pre-process data - Transform data - Build process data models - Data validation	- Enriched event logs - Process data model
Process Discovery and Analysis	- Strategically aligned vision and scope statements - List of initial hypothesis - Enriched event logs - Process data model	- **Process Mining Consultant** - Process Manager (SME) - Master Data Owner (Optional)	- Create process digital twin model - Analyze variants and indicators - Process analysis - Root Cause Analysis (RCA)	- Fact-based process flow model - Insights driven by value - Customized dashboards - List of potential automation or optimization areas

Table 6.1: The pre-requisites, output, required roles, and the activities of each phase

Phase	Prerequisites	Roles	Activities	Output
Deliver Insights	- Insights driven by value - Customized dashboards	- **Process Mining Consultant** - Process Manager (SME) - Process users	- Deliver findings - List potential enhancements - Impact/ Effort prioritization	- List of prioritized automation or optimization areas
Improvement Planning	- List of prioritized automation or optimization areas	- **Process Manager (SME)** - Process owner - Process Mining Consultant - Process users	- Develop the business case - Budget approval - Define improvement plan	- Business case for improvement initiative - Improvement project plan
Process Improvement	- Business case for improvement initiative - Necessary insights for formulating the requirements for change - Improvement project plan	- **Implementation Manager** (Change Manager-Organizational/Operational, Service Delivery Manager) - Process Mining Consultant - Process Manager (SME)	- Gather requirements for change - Implement process improvements - Monitor Progress	- Changed process / way of working - Process-related data of modified process
Measure Results	- Modified process/ way of working - Modified process-related data	- **Process Mining Consultant** - Improvement Project Manager - Process owner - Process Manager (SME) - Master Data Owner (Optional) - Process users (Optional)	- Training and Enablement - Analyze performance indicators - Realize Value	- Data-driven insights from the improved process. - Value realization
Support Continual Improvement	- Live process-related data connection	- **Improvement Project Manager** - Process Mining Consultant - Process owner - Process Manager (SME)	- Marketing the realized value - Prepare documentation - Provide operational support - Implement continual improvement	- Continual process improvements - Managed business continuity - Operational Excellence

Table 6.1: The pre-requisites, output, required roles, and the activities of each phase

The rest of this section comprises subsections dedicated to each of the seven steps in ITIL Continual Improvement Model as incorporated in PM4CSI. The explanation for the characteristics and activities associated with each step is presented in each of the subsections. Similar to the visual diagram of PM4CSI, the attributes and activities are based on the literature review results and framework refinement interviews' results. As for the visual diagram of PM4CSI, most of the information on the activities and other characteristics are based on the framework refinement expert interviews. The roles responsible, the prerequisites, the outcome, and the actions in the following subsections are drawn from the findings of the framework refinement interviews described in section 5.2 and 5.3, unless otherwise stated.

6.2.1 What is the vision?

The focus areas of this step is to understand and create a high-level vision for the improvement project. The formulation of the desired state should emphasize the value that might be created for the stakeholders rather than on the outputs [2]. The target state's vision and benefits should be communicated to all stakeholders. Table 6.2 shows the PM4CSI activities integrated with the *What is the vision?* step along with the activities, their description and related actions to be taken.

Project Initiation

For the above mentioned objectives, the first phase of PM4CSI,*Project Initiation* has been mapped to the *What is the vision?* step of ITIL Continual Improvement Model. *Project Initiation*, phase is comprehensive as failing to plan an improvement initiative is planning to fail. The success of process mining depends on the 3P's - People, Purpose, and Process instances as shown in Figure 3.13 and is determined during this phase. Figure 6.3 illustrates the activities performed during the Project Initiation phase.

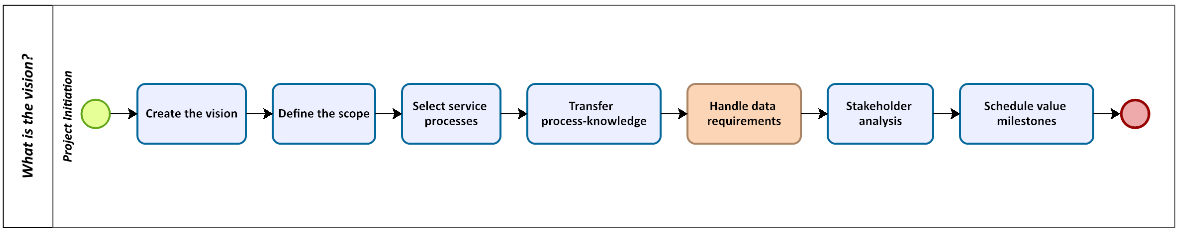

Figure 6.3: Activities during *Project Initiation* Phase

During the *Project Initiation* phase, the following activities are performed over one or more collaborative sessions.

- **Create the vision** - The first and foremost action is to define the North Star, i.e. the significant value of the improvement project, establish business goals, and develop a preliminary business case. Organizations constantly analyze industry benchmarks and/or industry best practices for seeking performance-level indicators of their business processes, such as striving to stay in the top quartile to have a competitive advantage. Such industry benchmark analysis would allow for defining the objective of the improvement project. Also, it is beneficial to have baseline metrics for our future analysis. One efficient method to define business goals is to follow SMART [1] objective method for effective results-oriented action. The vision of the improvement initiative should be value-focused, and all stakeholders must be committed to the vision. It is essential for the improvement

[1]SMART refers to Specific, Measurable, Attainable, Realistic and Time-bound goals [87]

project's goal to be strategically aligned with the organizational objectives and to produce value-driven outcomes. Once the vision is created with what is required to be achieved through the improvement initiatives, it is important to translate the goals into all levels of KPIs, i.e. strategic, technical and operational.

- **Define the scope** - The next step is to identify the problem areas and define the scope of the improvement project. Stemming from organizational strategy, the deviations should be identified. If there is no precise orientation of vision and scope for the improvement initiative, it is likely to fail. A set of hypotheses and abstract business questions can be formulated with the baseline metrics, goals, and problem areas. Then, a high-level business plan must be developed to create an overarching goal for the improvement initiative. Based on the identified problem areas and corresponding objectives, suitable process mining tool should be chosen for process mining analysis. License for the selected process mining tool should be obtained before continuing to the next phase.
- **Select service processes** - Once the project scope is defined and a high-level business plan has been developed, check for the feasibility of the process. It is essential to check if the data associated with the process is being tracked in the organizational information systems.
- **Transfer process-knowledge** - A session for the process mining technical expert to understand the operational aspect of the process should be conducted with the process owner and process analyst. It is vital to gather the list of KPIs and PPIs specific to the selected service process based on the overarching objective of the improvement project.
- **Handling data requirements** - It is essential to check data availability and identify the associated data source systems. Minimal data requirement for process mining project includes case ID, activity and timestamp associated with each event. However, based on the business questions, it is necessary to include additional dimensions that would add value to process analysis. Table 6.3 presents specific data quality aspects [88, 89] to be checked throughout the process mining project. The underlying quality of data should be considered since it impacts the results of the process mining analysis. Lastly, handling information security and regulations for accessing data and data source systems is crucial. The data privacy team should align on the data that must be anonymized or subjected to a confidentiality clause.
- **Stakeholder analysis** - The success of the improvement initiative depends heavily on onboarding the human resources committed to the initiative. Hence, it is essential to identify the relevant stakeholders and compose the project team for the improvement project.
- **Schedule value milestones** - For any project, it is essential to plan and schedule the milestones. Since the improvement initiative is value-driven, the milestones are best set based on value delivery. Setting up value milestones helps you assess how long the improvement project should take, determine the resources needed, and plan the order in which the tasks will be completed. They are also helpful for managing the dependencies between tasks.

6.2.2 Where are we now?

Since the success of any improvement project depends on an accurate understanding of the starting point and the project's impact [2], the main objective of this step is to ensure that the current practices are sufficiently understood, as well as their strengths and weaknesses relevant to the improvement being planned. It is essential to ensure that all relevant stakeholders are involved in the assessment and that assessment methods and results are visible to all. During

WHAT IS THE VISION?				
PM4CSI Phase	***Phase Owner***	***Activities***	***Description***	***Actions***
Project-Initiation	Improvement Project Manager	Create the vision	Determine why the project was created and strategically align the vision and objectives	• Define significant value of the improvement initiative • Establish business goals • Analyze industry benchmarks • Strategically align the goals with the organizational objectives • Define baseline metrics for future analysis
		Define the scope	Detail on how you will achieve the vision or task at hand	• Identify the problem areas • Define the project scope • Define hypothesis • Define high-level business plan
		Select service processes	Selection of service processes that are required to be analyzed	• Consider process characteristics • Check if related data is tracked in the organizational information systems
		Transfer process-knowledge	Understanding of the selected process for process analyst to effectively perform analysis	• Conduct session for undertanding the process to be analysed • Gather list of KPIs and PPIs related to concerned process
		Handle data requirements	Determine the data source systems, availability of data, and handle regulations	• Check for data availability • Identify data source information systems to extract data • Ensure data security and grants for access and permissions
		Stakeholder analysis	Compose project team to efficiently execute the project plan with different roles and expertise	• Identify relevant team members • Allocate responsibilities • Ensure clear communication of responsibilities, business objectives and business questions.
		Schedule value milestones	Provision of a structure and foresight for the execution stage, helping to eliminate wasteful activities and patterns	• Identify dependencies between tasks and responsibilities • Plan and schedule project milestones • Ensure the milestones are value-driven

Table 6.2: Activities, their description and required actions during *What is the vision? - Project Initiation* phase

this phase with the help of process mining and analysis techniques, the hypothesis will be approved or disapproved in a data-driven way.

The evaluation of the current state includes assessing the services, users' perception of value received, people's competencies and skills, processes, and technological capabilities. Along with the traditional approach of assessing these elements to workshops, a data-driven approach enables objective measurement. Process mining analysis provides visibility of any grey areas where the current state is not fully understood. Therefore, the next three phases of PM4CSI, *Data Ingestion*, *Data Preparation*, and *Process Discovery and Analysis* phases, have been mapped to *Where are we now?* step of ITIL Continual Improvement Model. Table 6.4 shows the PM4CSI phases integrated with *Where are we now?* step along with the associated activities, their description and related actions to be taken.

Data Ingestion

This phase aims to obtain and import data from one or more data sources to process mining tools for further processing and analysis. To execute this phase, a proper license should be purchased from process mining vendors. Such modern process mining tools facilitate direct ingestion of process-related data into the tool with the concept of pre-designed adaptors or extractors specific to different data source information systems. Figure 6.4 illustrate the activities performed during the *Data Ingestion* phase.

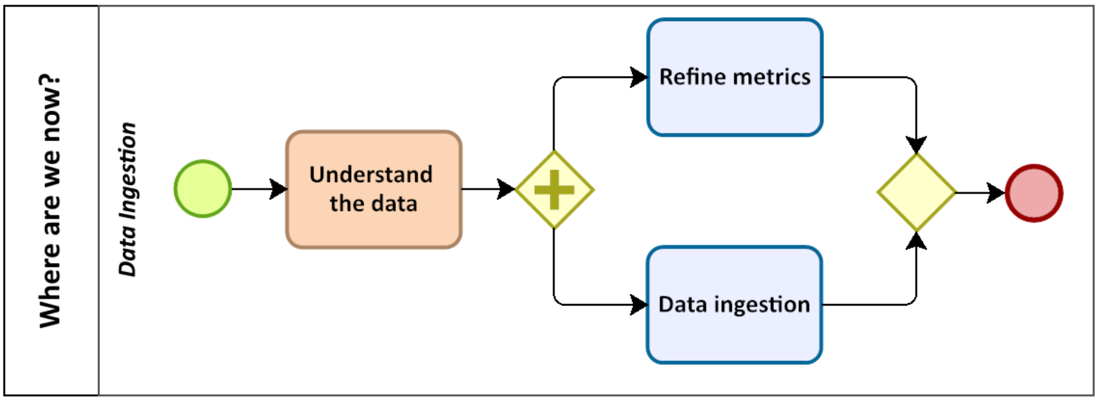

Figure 6.4: Activities during *Data Ingestion* Phase

During the *Data Ingestion* phase, the following activities are performed.

- **Understand the data** - Based on the problem areas, the scope of the data should be determined, i.e. deciding which data attributes contribute to the process analysis, within which time period, and at which level of granularity. A data understanding session through interviews or brainstorm workshops should be conducted with process owner, data owner, and process analyst to understand how the data is associated with the events of the process to be analyzed. The data quality should be checked during this activity as this step is also the first glimpse of actual data attributes and entries.
- **Refine metrics** - After understanding the data and its quality, it is important to refine the KPIs and PPIs to be analyzed based on the availability of relevant data columns. The redefined list of KPIs will be the metric to analyze and measure results.
- **Data ingestion** - Data ingestion happens in two ways depending on the maturity of process mining in an organization.
    1. When the organization has process mining tool interface integrated with their IT

architecture, then data connection can be established by adaptors(also known as connectors or extractors) specific to data source information systems. Such adaptors map logs from different PAIS. By ingesting dynamic data through data connectors, the format of the data being ingested is not a hard criteria for analysis with process mining techniques. It also enables analysis on real-time dynamic data by scheduling periodic data jobs.

2. If organization does not have a meaningful process mining provision, or it one-time service is opted, then data files are extracted from identified data source systems and are manually ingested into the process mining tool. The format of files to be ingested depends on the choice of process mining tools and mostly all process mining tools work with CSV, XES or any structured data that can be configured with SQL language. However, the data extracted from PAIS such as ServiceNow and Salesforce are usually flat file format and are compatible with the process mining tools.

Data Preparation

The main objective of the *Data Preparation* phase is to create event logs in such a way that it is optimal for Process Discovery and Analysis phase. Figure 6.5 illustrate the activities performed during the *Data Preparation* phase.

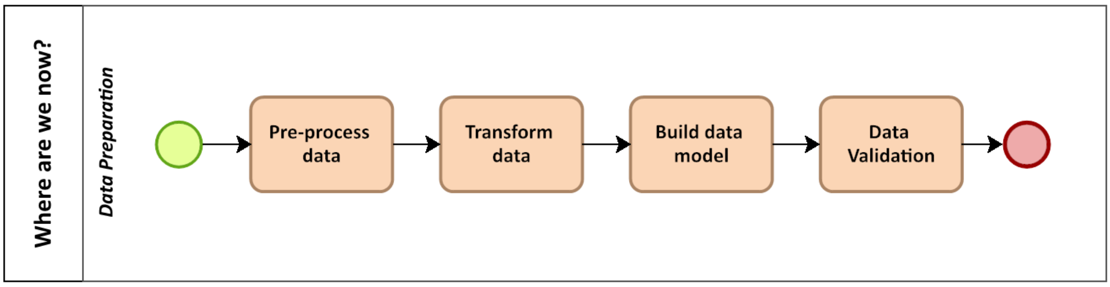

Figure 6.5: Activities during *Data Preparation* Phase

During the *Data Preparation* phase, the following activities are performed.

- **Pre-process data** - The objective is to identify the quickest approach to address data quality issues, such as removing inaccurate data, filling data gaps, or generally making sure the raw data is appropriate for process mining analysis.
- **Transform data** - The aim is to transform how various data elements should be arranged in order to best serve the goal. The events are aggregated or specialized to reduce complexity and improve structure of the results. This may entail actions like organizing unstructured data, integrating relevant variables when it makes sense, or selecting crucial ranges to pay attention to. The data is transformed to an enriched event log that can be used for process mining and analysis. Another important activity is to map same data fields from different sources that has different semantics and naming conventions to avoid ambiguity during the Process Discovery and Analysis. The process mining tools allow uploading flat files that contains data mapping schemes for data from multiple source systems. Although the tool provides automated solution, it is best to adopt a hybrid process between fully automated and manual mapping.
- **Build process data model** - The aim is to create the fact and dimension tables following a star schema to produce process data model. The data attributes of the enriched event log are assigned as case level and event level attributes.

Data Quality Dimensions		Description
Level of abstraction of event		Low: if event refers to movements within a task; Average: event refers to individual task; High: event refers to a collection of tasks
Accuracy of timestamp	Granularity	High: milliseconds; Average: hour/minute; Low: day
	Directness of registration	High: directly registered; Low: registered later
	Correctness	High: Logged correctly given the chosen level of granularity; Low: otherwise
Missing data		Missing certain log entities such as an event, attributed and relation.
Incorrect data		Incorrect logging of data based on contextual information
Imprecise data		Coarse data entities leading to lack of precise value
Irrelevant data		Logging irrelevant data entitie

Table 6.3: Data quality checks to be carried out throughout process mining project suggested by [88, 89]

- **Data Validation** - Although, the data quality checks are performed throughout this phase, during this step, it is essential to have in-depth verification of the data quality that has been prepared for the process mining analysis. The data engineer and/or process analyst working on the data preparation phase should check for the aspects mentioned in Table 6.3 and ensure sufficient data has been presented to the next step of this phase.

Process Discovery and Analysis

Once the event log is prepared and enriched, the next step is to discover the actual process model and perform analysis. Based on the level of abstraction with the business questions, an exploratory approach of process mining can be adopted to acquire an overall view of the selected service process. The main objective of this phase is to apply process mining techniques on event logs and focus on answering the business questions to generate data-driven valuable insights. The findings of the analysis should be based on value realization.

Figure 6.6 illustrate the activities performed during the *Process Discovery and Analysis* phase. The following activities are performed during the *Process Discovery and Analysis* phase.

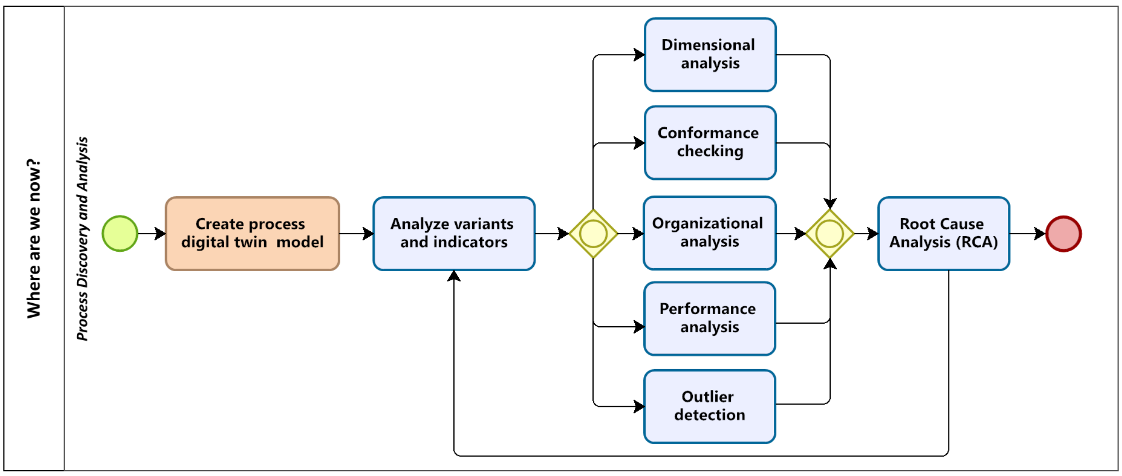

Figure 6.6: Activities during *Process Discovery and Analysis* Phase

- **Create process digital twin model** - As extensive Process Discovery phase is presented in academic literature, in practice, with process mining tools available in market, process discovery is a very minimal phase. A digital twin of the process is discovered during this activity. Quality of data is also verified during this activity to ensure relevant and efficient insights are generated at the end of this phase. If the discovered process model displays the aspects for poor quality of data, then the process mining technical expert might iterate to *Data Preparation* activity to perform further data manipulation and transformation.

- **Analyze variants and indicators** - Once the process digital twin is discovered, the first glimpse of process variants will be provided by the process mining tools. This step is to discover different process variants (frequencies, traces, and performance measures) and identification of the most prevalent ones. By analyzing the variants of the process and how connections are happening across different events in a process trace. The possible execution gaps and indicators for process in focus can be identified by discovering the variants and process digital twin model.
- **Process Analysis** - Different process mining techniques such as conformance checking can be applied during this activity. Numerous papers in the field of process mining, where process analysis takes up a substantial portion of the actual reasoning, emphasize the necessity of classical process analysis alongside Process Mining [42, 67, 9]. Combination of the following analysis can be carried out on the discovered process to produce insights for optimization:
  - *Conformance checking:* Refers to comparing the as-is process to the desired model. Conformance describes how far and in how many scenarios the as-is process deviates from the ideal model. Furthermore, discovery can help reconstruct a realistic model that captures the actual complexity behind the process. The inputs for this type of process mining are Event Logs and process models, and the expected output is diagnostics [39].
  - *Process exploration*: Evaluation of discovered process model and further exploration of a satisfying model [44, 45].
  - *Decision point/ Dimensional analysis*: Extension of an existing model with data-related attributes (e.g. age, gender, product category)
  - *Organizational analysis*: Establishing a social network, identifying relationships between organizations or roles, or extending an existing model to include resource characteristics [44, 45].
  - *Performance analysis*: Process performance analysis aiding the identification and quantification of bottlenecks [44, 45].
  - *Performance target analysis*: Identification of problematic cases by filtering them according to the baseline or target value [44, 45].
  - *Outlier detection*: Detecting the occurrence abnormal values in event logs [44, 45].
  - *Enhancement*: Refers to all actions and measures of improvements taken to bring the as-is process closer to the desired model. It encompasses any feedback from the real world, including predictions and recommendations. As a research field, Enhancement opens up an entirely new world for the adaptation and use of process mining within organizations and how it helps create actual business value and insights. The inputs for this type of process mining are Event Logs and process models, and the expected output is a new process model [39].
- **Root cause analysis** - Impact factors such as bottlenecks and outliers might contribute to process issues. Finding process errors and their causes and then analyzing them is the goal of root cause analysis. The percentage of errors with the same cause can be calculated using these studies. Process mining tools offer automated root cause analysis

WHERE ARE WE NOW?				
PM4CSI Phase	***Phase Owner***	***Activities***	***Description***	***Actions***
Data Ingestion	Process Mining Consultant	Understand the data	Data understanding session to transfer data knowledge associated with the identified problem areas	– Identify relevant tables and understand the data and their relationships with the identified problem areas – Check for data quality
		Refine Metrics	Understanding and agreeing to new set of process performance indicators based on the available data	– Refine the list of performance metrics
		Data Ingestion	Ingesting raw data into the process mining tool	– Identify the type of data connection required (i.e. direct data connection or uploading flat files) – Set up data connector in case of live data connection – Extract required raw data files, in case of one-time analysis – Ingest files into the process mining tool for further analysis
Data Preparation	Process Mining Consultant	Pre-process data	Pre-process data to address the data quality issues	– Perform typical pre-processing steps such as cleaning the data by filling the gaps or removing attributes.
		Transform data	Transform the data to an enriched event log	– Perform aggregating events and enriching event logs for process analysis – Mapping data columns from multiple data source systems to make semantic sense – Building one or more event/activity tables and check for data quality issues if any.
		Build process data models	Determine the flow of data between created tables	– Connect different tables to create a process data model to eliminate redundancy and efficiently retrieve data during process analysis.
		Data validation	Determine the accuracy and quality of data from multiple source systems	– Perform data quality checks for mitigating any defects in the analysis
Process Discovery and Analysis	Process Mining Consultant	Create process digital twin model	Create direct insights into the as-is process model	– Discover the process model – Validate the data by check for open and close activities and process flow
		Analyze variants and indicators	Perform variant analysis	– Analyze the variants and check for the identified performance indicators – Check and verify the basic metrics
		Process analysis	Process of process mining and analysis	– Combination of process mining analysis techniques to be used to answer the business questions
		Root Cause Analysis (RCA)	Ways for root cause analysis of selected tables	– Analyze the root causes of poor performance related to identified indicators – Involve process expert to understand the domain problems and connect insights with the real world

Table 6.4: Activities, their description and required actions during *Where are we now?* phase

modules to perform root cause analysis of the single dimensions contributing to poor performance concerning defined performance indicators. The automated root cause analysis in process mining tools uses algorithms like causal theory [90] to find the important influencing variables of an issue in a process. The algorithm looks for obvious structures, patterns, and correlations in the discovered data to determine which has the greatest influence behind the poor performance indicators. However, it is recommended to perform a hybrid root cause analysis by involving process experts to validate the root causes of a specific issue. Recommended root cause analysis approaches are Five Whys[2], Kepner-Tregoe[3], Pareto Analysis[4], and Fishbone tool[5].

During the process analysis and root cause analysis phases, it is still advised to adhere to the original principle of using innovative technology in conjunction with the brilliance of the human intellect and domain expertise to solve the most challenging issues. The results of this phase can be created as customized dashboards depending on the results of the business questions and presentation to different roles.

6.2.3 Where do we want to be?

The main objective of this step is to evaluate the gaps in the process and prioritize the improvement actions to reach the target state. The improvement objectives are set along with KPIs and critical success factors. It is essential to ensure that the improvement ideas sufficiently reflect the vision and scope.

Deliver Insights

For the above-mentioned objectives, the fifth phase of PM4CSI, *Deliver Insights*, has been mapped to the *Where do we want to be?* step of the ITIL Continual Improvement Model. Figure 6.7 illustrates the activities carried out during the *Deliver Insights* phase. Table 6.5 shows the PM4CSI activities integrated with the *Where do we want to be?* step along with the activities, their description and actions to be taken.

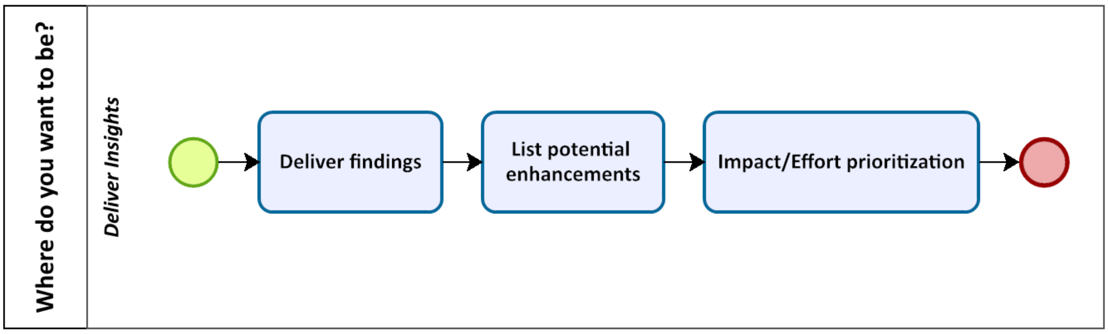

Figure 6.7: Activities during *Deliver Insights* Phase

The following activities are performed during the *Deliver Insights* phase.

- **Deliver findings** - The findings and insights from the outcome of the previous phase will be based on value realization. Generally, the insights from a process mining analysis could be an organizational change or process/ workflow redesign. Process mining analysis can approve or disapprove the hypothesis from the *Project Initiation* phase. The process analyst should present the insights to the process experts for evaluation. The information on the performance indicators related to the use and improvements of the process should be delivered to the business users during this activity. The business questions can be redefined or new business questions can emerge. It is possible to re-iterate to *Process*

[2]Information on *5 Whys* can be found here
[3]Information on *Kepner Tregoe* can be found here
[4]Information on *Pareto analysis* can be found here
[5]Information on *Fishbone Tool* can be found here

Discovery and Analysis phase to perform further process mining analysis after discussing the findings with the business users.

- **List potential enhancements** - Process mining can result in one or more following improvement actions: *Redesign, Adjust, Intervene, Support* [91]. During this activity, the process analysts and the process experts work collaboratively to evaluate the findings for correctness. Evaluating the findings includes: correctly interpreting the results and distinguishing unusual versus interesting results The major challenge to be noted during this activity is the duration of waiting for the validation of insights. The identified use cases should be aligned with the strategic objectives identified during the *Project Initiation* phase. This activity's outcome is a list of potential improvement ideas based on the expected value those might generate.
- **Impact/Effort prioritization** - The interventions suggested as improvement use cases should be prioritized based on the effort required and the business value the improvement could generate. An effort-impact matrix is a decision-making tool that helps to choose the best use cases based on relative effort and impact. It is a straightforward prioritization matrix adopted in the business context. Figure 5.6 shows the industry best practice of the Impact/Effort matrix. Having proper metrics and ignoring cognitive biases is crucial to avoid planning fallacy during this activity. Again, the objectives should be aligned to assess the current state and address all key improvement opportunities. The use cases that fall under *Money Pit* categories are dropped and not included for process improvement. The outcome of this activity is a list of prioritized use cases based on the Return on Investment (ROI) and value.

6.2.4 How do we get there?

The main objective of this step is to plan measurable actions after gathering sufficient feedback from the process owners and users in the previous phase. It is vital to ensure that all relevant stakeholders understand and accept action plans. It is also essential to keep the improvement actions as simple and realistic steps with clear outputs defined. Table 6.6 shows the PM4CSI activities integrated with the *How do we get there?* step along with the activities, their description and actions to be taken.

Improvement Planning

For the above-mentioned objectives, the sixth phase of PM4CSI, *Improvement Planning*, has been mapped to the *How do we get there?* phase of the ITIL Continual Improvement Model. Figure 6.8 illustrates the activities carried out during the *Improvement Planning* phase.

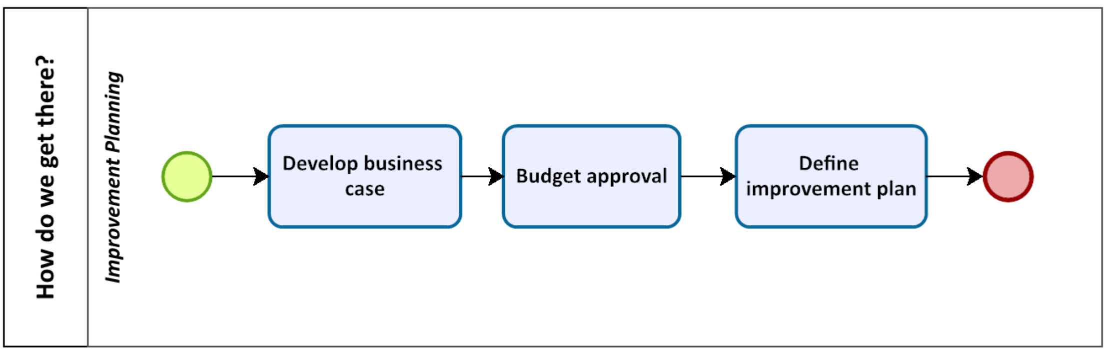

Figure 6.8: Activities during *Improvement Planning* Phase

WHERE DO WE WANT TO BE?				
PM4CSI Phase	***Phase Owner***	***Activities***	***Description***	***Actions***
Deliver Insights	Process Mining Consultant	Deliver findings	Delivery of insights derived from the process mining analysis	• Communicate and evaluate the findings with the process experts/ users • Reiterate to process mining analysis when needed
		List potential enhancements	Deriving at accurate and correct improvement ideas	• List potential improvement ideas based on value • Check if ideas align strategically with the project objectives
		Impact/ Effort prioritization	Prioritization of the use cases for process improvements	• Perform Impact/ Effort analysis on the derived improvement ideas • Derive only prioritized use cases based on ROI and value

Table 6.5: Activities, their description and required actions during *Where do we want to be?* phase

HOW DO WE GET THERE?				
PM4CSI Phase	***Phase Owner***	***Activities***	***Description***	***Actions***
Improvement Planning	Process Manager (SME)	Develop the business case	Develop business case for prioritized use cases	• Derive justifications for executing the improvement action plan by evaluating the benefit, cost, risk, and rationale for the suggested action.
		Budget approval	Get the improvement project approved, sponsored, and resourced	• Create a brief and simple budget proposal to secure sponsorship for the improvement initiatives.
		Define improvement plan	Defining program or method ahead of improvement project	• Create a simple and realistic improvement plan with correct steps, a clear definition of outputs, required stakeholders, and timelines. • Communicate with relevant stakeholders

Table 6.6: Activities, their description and required actions during *How do we get there?* phase

TAKE ACTION				
PM4CSI Phase	***Phase Owner***	***Activities***	***Description***	***Actions***
Process Improvement	Implementation Manager* (Organizational Change Manager/Operational Change Manager/ Service Delivery Manager)	Gather requirements for change	Gather requirements for process improvements	• Elicit requirements from the stakeholders and communicate them.
		Implement process improvements	Executing the improvement action plan	• Follow specific project or program methodology for process improvements
		Monitor Progress	Iteratively monitoring the progress of the process improvement project	• Verify the improvement activities are going as planned

Table 6.7: Activities, their description and required actions during *Take Action* phase

The following activities are performed during the *Improvement Planning* phase:

- **Develop the business case for identified use cases** - During this activity, it is necessary to develop a business case for every prioritized use case identified during the last phase.
- **Budget approval** - The improvement plans can only be executed when the sponsor aligns with the business case, improvement ideas and the expected value and sanctions the budget required for implementing the improvement.
- **Define improvement plan** - Process mining improvements do not necessarily lead to a process redesign. For instance, the improvement ideas could be implementing training sessions for the service support team for better scoring of First Call Resolution (FCR), a customer service metric. Based on the initiative's vision and the analysis results and goals, a simple and not complex improvement plan for addressing the challenges should be co-created with the process experts. Tools such as Kanban should be used to ensure the visibility of the improvement plan. The improvement plan should encompass realistic steps, a clear definition of outputs, required stakeholders, and timelines. It is vital to ensure that the objectives are sufficiently reflected in the improvement action plan and is communicated to the required stakeholders.

6.2.5 Take action

The main objective of this step is to execute the improvement plan. Improvements can be big or small initiatives which are significant in generating value for the business. Table 6.7 shows the PM4CSI activities integrated with the *Take Action* step along with the activities, their description and actions to be taken.

Process Improvement

The primary motivation of a process mining project is to achieve process improvements [67]. Hence, the seventh phase of PM4CSI, *Process Improvement*, has been mapped to the *Take Action* step of ITIL Continual Improvement Model. This phase should be considered the value creation phase, where process improvements are initiated. The improvement ideas are usually to eliminate, extend, and/or improve existing process models or workflow implementation. So based on the prioritized use cases, the selection of use cases for process improvements takes place during this phase. However, the actual implementation of process change is generally a separate project. Figure 6.9 illustrates the activities carried out during the *Process Improvement* phase.

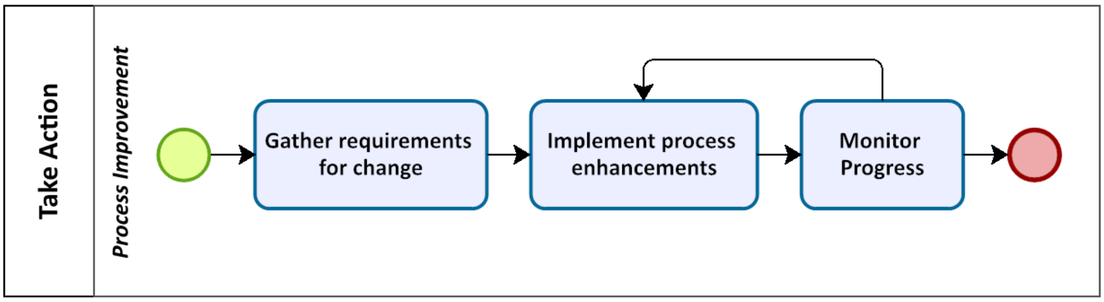

Figure 6.9: Activities during *Process Improvement* Phase

Since creating of program or project management is a different area of expertise, this phase of the PM4CSI should be treated as a black box, and the following activities should be performed during the *Process Improvement* phase.

- **Gather requirements for change** - During this activity, it is required to gather requirements for process improvements based on the improvement plan derived from the results of process mining analysis.
- **Implement process improvements** - Based on the type of improvements, specific project or program should be implemented. During this activity, as the process is being modified, it is essential to consider the constant changes in regulations and processes surrounding the improvements. Thus, it is recommended to implement process improvements in an iterative manner. It allows to capture and analyze feedback and where appropriate adjust the improvement action accordingly.
- **Monitor Progress** - Verify that improvement activities are going as planned during this activity, and introduce corrective actions as needed.

6.2.6 Did we get there?

The main purpose of this step is to check the targets to ensure that the objectives have been attained. Progress and value should be measured and validated to success. The key metrics defined before the process improvements should be measured to validate the outcome of the process improvement with the value it generated. It is essential to have mapped the metrics with the outcome of the improvement initiative appropriately and communicated with all relevant stakeholders. Table 6.8 shows the PM4CSI activities integrated with the *Did we get there?* step along with the activities, their description and related actions to be taken.

Measure Results

For the above-mentioned objective, the eighth phase of PM4CSI, *Measure Results*, has been mapped to the *Did we get there?* step of the Continual Improvement Model. This phase should be considered the value realization phase, where process improvements are measured objectively. The most important requisite for conducting the activities of this phase is the process-related data of the modified process. Hence, data should be collected to measure the improvements and associated value. Figure 6.10 illustrate the activities performed during the *Measure Results* phase.

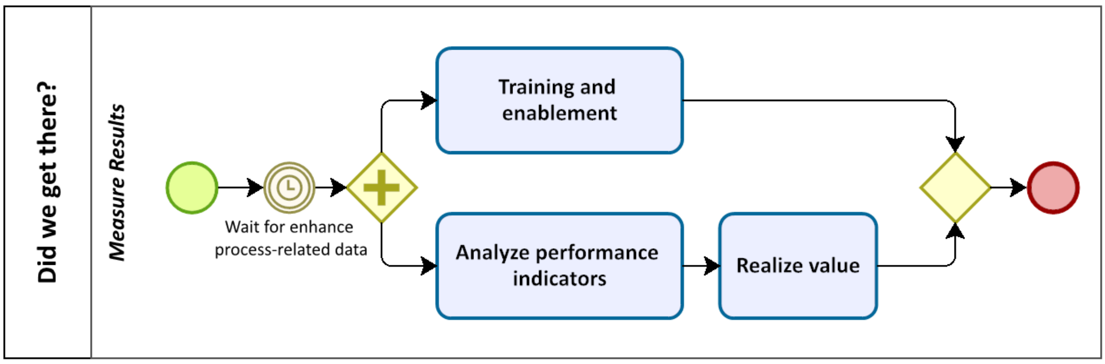

Figure 6.10: Activities during *Measure Results* Phase

During the *Measure Results* phase, the following activities are performed.

- **Training and Enablement** - During this activity, training is provided for relevant stakeholders on how to continue using the process mining tool for continually improving and monitoring their processes. it is important to make sure that the stakeholders understand and use the information from the process mining tool. The facilitator should encourage discussions, and highlight the possible deviations during the training activity.

DID WE GET THERE?				
PM4CSI Phase	***Phase Owner***	***Activities***	***Description***	***Actions***
Measure Results	Process Mining Consultant	Training and Enablement	Provision of training to enable users to use the process mining application	– Conduct training sessions through workshops or videos to provide knowledge on how to continue using the platform without the help of the process mining analyst.
		Analyze performance indicators	Assessment of target state to measure improvements	– Analyze the process flow and the improvements in the KPIs with changed process data
		Value realization	Realizing expected value through process improvements	– Deliver insights of the improved process such that it covers the objectives of the improvement initiatives – Provide customized metric as per business needs

Table 6.8: Activities, their description and required actions during *Did we get there?* phase

HOW DO WE KEEP THE MOMENTUM GOING?				
PM4CSI Phase	***Phase Owner***	***Activities***	***Description***	***Actions***
Support Continual Improvement	Improvement Project Manager	Marketing the realized value	Promotion of the realized value	– Involve the marketing team in promoting the success of the realized value for holistic and firm-wide adoption of process mining improvement initiatives.
		Prepare documentation	Create current project closure report	– Conduct performance review regarding schedule, cost, and quality. – Identify lessons learnt and future opportunities. – Finalize documentation and index them in the archives for later reference.
		Provide operational support	Setup process mining tool support for continuous monitoring	– Monitor the dashboard to perform operational support
		Implement continual improvement	Continue implementing the activities of the improvement initiative	– Iterate to Improvement Planning phase if other use cases are available for improvement – Iterate to Project Initiation phase to identify new problem areas for optimization.

Table 6.9: Activities, their description and required actions during *How do we keep the momentum going?* phase

- **Analyze performance indicators** - If the data ingestion is through uploading raw data files, then the second, third and fourth phases of PM4CSI should be followed again with the updated process-related data of the modified process. Otherwise, there exists data connection with live data ingested with scheduled data jobs. Process enhancements are usually measured by tracking KPIs in a programmatic software. With the modified process-related data, analyze the KPIs and PPIs to measure the improvements quantitatively. It is recommended to include all metrics defined during the project and all aspects of the initiative such as effectiveness, compliance, efficiency, and performance.
- **Value realization** - The activity is named as *value realization*, because the insights delivered with changed process data directly equates to the delivery of value through the process mining improvement initiative. The process analyst should
ensure that the measurement and delivery of insights sufficiently cover the objectives of the improvement initiatives. It is important to address different levels of metrics to different roles based on their position in the organization. Global process owners often look up for strategic KPIs related to the changed process. During this activity, the process mining analyst delivers the insights which reflects the value realized by undergoing the process mining improvement initiative to all the relevant stakeholders.

6.2.7 How do we keep the momentum going?

The main objective of this step celebrate and market the success of the improvement initiatives on the event of delivering the expected value set [2] during *Project Initiation* phase. This step should not be skipped to ensure long-term improvement. The improvement initiative should be repeated over and over continually to verify vision and align the actions to changing environment. Table 6.9 shows the PM4CSI activities integrated with the *How do we keep the momentum going?* step along with the activities, their description, and related actions to be taken.

Support Continual Improvement

For continuing the momentum achieved through the improvement initiative, the last phase of PM4CSI, *Support Continual Improvement*, has been mapped to the *How do we keep the momentum going?* step of ITIL Continual Improvement Model. Figure 6.11 illustates the activities performed during the *Support Continual Improvement* phase.

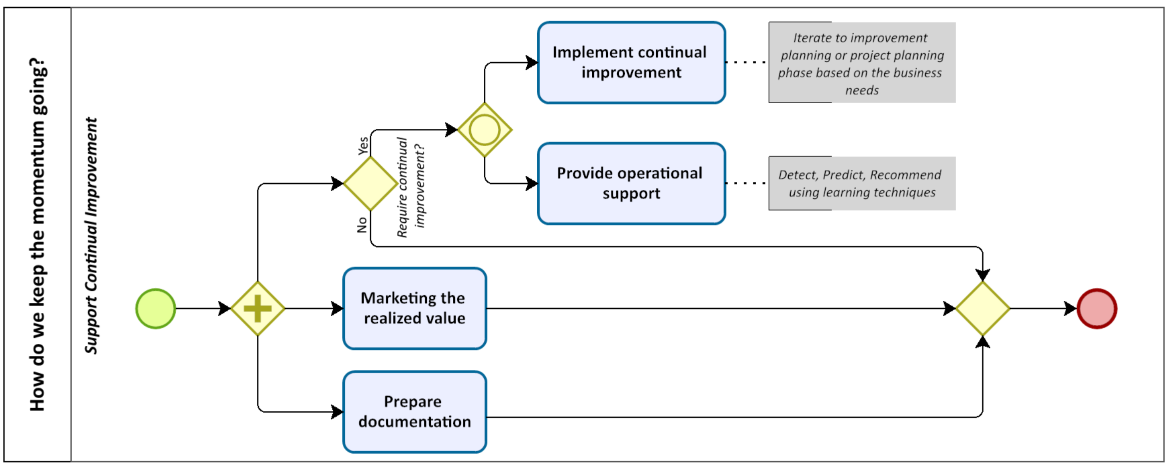

Figure 6.11: Activities during *Support Continual Improvement* Phase

The following activities are performed during the *Support Continual Improvement* phase.

- Besides the use of automation to capture new initiatives and feedback, to provide transparency, and to improve collaboration, the momentum can be continued by following one or more of the following activities.
  - **Provide Operational Support** - The Aalst L* Lifecycle Model depicts three kinds of operational support activities: detect, predict, and recommend. However, it is essential to have structured and high-quality results to implement this activity in an organization. With the help of data connection and customized dashboards, businesses can monitor the dashboard to perform operational support. This activity covers the necessary steps to implement the process mining solutions as Business As Usual.
    1. *Detect*: The operational support system continuously checks each case's partial trace; thus, each time an event happens, the operational support system is supplied the case's partial trace. The operational support system immediately generates an alarm if a deviation is found. Based on this alert, the enterprise information system and its users can take the necessary actions, such as notifying management so that corrective measures can be taken.
    2. *Predictive monitoring*: Prediction of violations or recommendation of best practices based on execution or simulation, for instance, 'The predicted remaining SLA is 3 hours.' [45, 39].
    3. *Recommend*: In contrast to prediction, the response is not a prediction but a recommendation about what to do next based on learning techniques of historic cases. Recommendations should always be set up with a specific goal, for instance, 'Follow up with the requester to meet SLA'. Performance indicators must be defined to set up supervised learning.
  - **Implement continual improvement** - One of the following routes can be taken to continue implementing the improvement project
    1. Iterate to *Improvement planning* phase if there are remaining use cases to be improved and follow the steps of PM4CSI
    2. Iterate to the *Project Initiation* phase to identify new problem areas if the process mining improvement initiative has to be carried out for another department or process.
- **Prepare documentation** - This activity is supported by the essential two main functions of documentation: to ensure that the project's criteria are met and to establish traceability regarding what has been done, by whom, and when. *Prepare documentation* activity is essential because project managers need to close contracts and get formal approval from stakeholders, among other important tasks. The reasons and lessons must be documented and communicated to the stakeholders.
- **Marketing the realized value** - Involve stakeholders in the marketing of improvements, make information about improvements widely available and encourage all stakeholder groups to develop new improvement initiatives [2]. When implementing a process mining project in an organization, it is essential not to limit improvement programmes and their marketing into a process as a silo. It should try incorporating as many processes or departments as possible to achieve holistic results. Consequently, owning a general process mining approach to achieve process optimization.

6.3 Summary

- The current chapter presented the refined version of the framework - PM4CSI V1.0, which was resulted from the literature study and saturated data collected and analyzed from two series of expert interviews.

- PM4CSI V1.0 framework comprises of three parts - a high-level graphical abstract, a detailed graphical overview, and a detailed explanation of the phases in the forms of texts, activity flow diagrams and tables.
- A graphical representation of the abstract level of PM4CSI V1.0 with the nine phases mapped to the seven steps of ITIL Continual Improvement Model can be seen in Figure 6.1. A detailed overview of the PM4CSI can be seen in Figure 6.2 illustrating the path of the improvement initiatives and the necessary iteration flows. Section 6.1 presented the main flow and detailed overview of the PM4CSI phases.
- Section 6.2 comprehensively discussed the attributes such as responsible roles, prerequisites, output, and relevant activities that should be performed for each phase of the PM4CSI V1.0 through explanatory tables, activity flow diagrams, and textual information.
- With the refined framework being designed and developed using empirical scientific methods, the next chapter discusses the validation process to justify that PM4CSI V1.0 would contribute to stakeholder goals when implemented in the ITSM process improvements.
- The difference between the initial version of the PM4CSI framework, PM4CSI V0.1, created solely by reviewing the scientific literature and the refined version, PM4CSI V1.0, by gathering information from industry experts shows the gap between academy and practice. It can be argued that the faster pace of advancements in the field of process mining creates such gaps between existing scientific documentation and organizational practice.

Chapter 7

Framework Validation

In this chapter, the validation process of this research has been addressed. Validating the framework designed and developed is essential to justify that PM4CSI V1.0 would contribute to stakeholder goals when implemented in the ITSM process improvements by showing that it satisfies the requirements specified in Section 2.2. The critical distinction between validation and evaluation is that while in validation, researchers experiment with a model of how stakeholders would use the artifact in the real world, in evaluation, researchers study an artifact in the real world that is used by stakeholders independently from the researchers [13]. Two episodes of validation namely expert opinion and case studies were adopted in this research. The following sections will explain the process in detail, summarizing the results from each validation episode.

7.1 Mixed-Method Validation Strategy

Design science validation research aims to understand the effects of applying the artifact in a real-problem context [13]. The mixed-method strategy for validation of this research follows the Framework for Evaluation in Design Science (FEDS) [22]. FEDS's evaluation design process consists of four steps:

1. Explicating the evaluation goals
2. Choosing the strategy or strategies for evaluation
3. Determining the properties to evaluate
4. Designing the episode(s) of individual evaluation.

In the context of the current research, the goal is to predict the effect of applying the Process Mining for Continual Service Improvement framework to improve the ITSM operations in an organization. Human Risk & Effectiveness strategy has been chosen as it is most appropriate for uncertainties with a socio-technical artifact and for establishing effectiveness in actual use. The validation model consists of the artifact model interacting with a model of the problem context [13]. In this research, the artifact model is the PM4CSI framework. Two validation episodes are used to simulate the context as they relate to the stakeholders who interact with the PM4CSI framework: (i) Expert interviews with process mining and ITIL consultants; (ii) case studies with different process mining market tools. The properties to evaluate are the evaluation criteria set up and presented in section 2.2. Figure 7.1 illustrates the evaluation episodes on the characterization of the FEDS [22].

The first validation method consists of expert interviews with process mining center of excellence consultants from different organizations and ITIL certified experts. This set of stakeholders

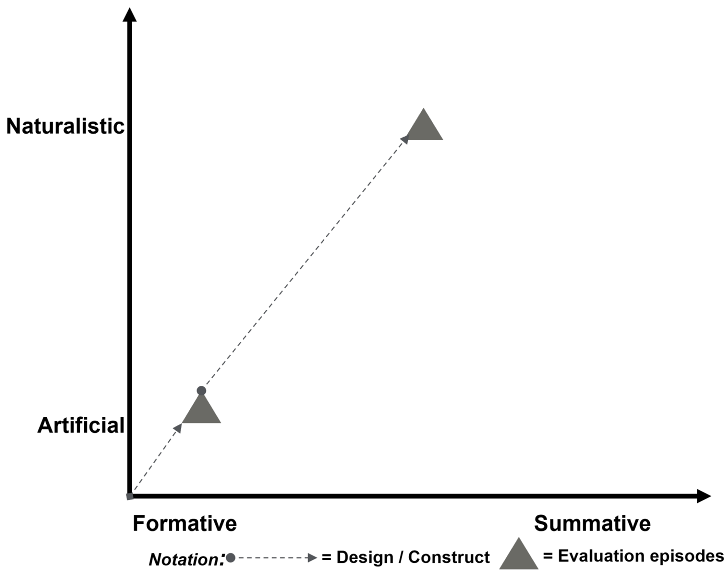

Figure 7.1: Evaluation Strategies adapted from FEDS [22]

represents the intended users of the PM4CSI framework and has experience with continual process improvements at multiple organizations. The process mining and continual improvement experts visualize the use of the PM4CSI in a real-world setting and then express their judgment on the evaluation criteria based on it. Consequently, such interviews result in an *artificial* evaluation paradigm. Multiple interviews with different consultants were performed to improve the validity and generalizability of the findings. The first validation episode was conducted mainly to satisfy the framework's Utility, Usability, Relevance and Comprehensiveness requirements.

The second validation method consists of case studies using process mining tools available in the market provided by different vendors. The incident management data from a public database and from an organization, a leading supplier of high-quality medical imaging equipment, who intended to improve their ITSM operations were used during the case studies. The stakeholder group is the functional beneficiary of the PM4CSI framework. For such validation, PM4CSI is improved based on the minor evaluation feedback from the first validation method. The purpose of this evaluation is more summative and naturalistic, as it aims to conclude the research. It explores the efficiency of the PM4CSI framework by assessing real-world processes and participants. Multiple case studies were performed to improve the validity and generalizability of the findings, along with evaluating the practicality and tool independence nature of the PM4CSI framework.

7.2 Expert Opinions

To understand the value of PM4CSI V1.0 in assessing and improving ITSM operations, One-on-One interviews were conducted with various experts from the field of ITIL and process mining. Each interview took roughly 45 to 60 minutes. With the consent of the interview participants, the interviews were recorded, and the interview minutes were transcribed.

7.2.1 Interview Participants

The first episode of validation consists of interviews to gather experts' opinions by interviewing the process mining experts and continual improvement consultants, the intended users of the PM4CSI framework. As they are the intended users, their opinion on the understandability, usefulness, practicality, relevance, and ease of use is essential. Table 7.1 shows the participants

Reference	Country	Current Position
VE1 (E18)	Canada	Operations Transformation Manager
VE2 (E19)	Germany	Process Mining Center of Excellence Lead
VE3(E10)	**Washington**	**Senior Process Mining Software Development Engineer**
VE4 (E20)	The Netherlands	Senior Manager
VE5 (E21)	The Netherlands	Manager
VE6 (E22)	The Netherlands	Senior ServiceNow Consultant
VE7 (E23)	India	Technical Lead

Table 7.1: Evaluation Interview Participant Details

of the expert evaluation, and Figure 7.2 shows the participants' years of experience in process mining and continual service improvements. The row in bold font represents a participant from framework refinement interviews (refer Table 5.1). Partaking participants from framework refinement interviews is essential, as they can validate that the PM4CSI interpretations are built on their expertise, which is called member checking [13]. Each participant is referenced as VE'X', which is used as a code to substantiate comments of the model in Section 7.2.3 based on the interview minutes, recorded and transcribed, which can be provided upon request. For more details on the interviewees' profile, refer Table A.2

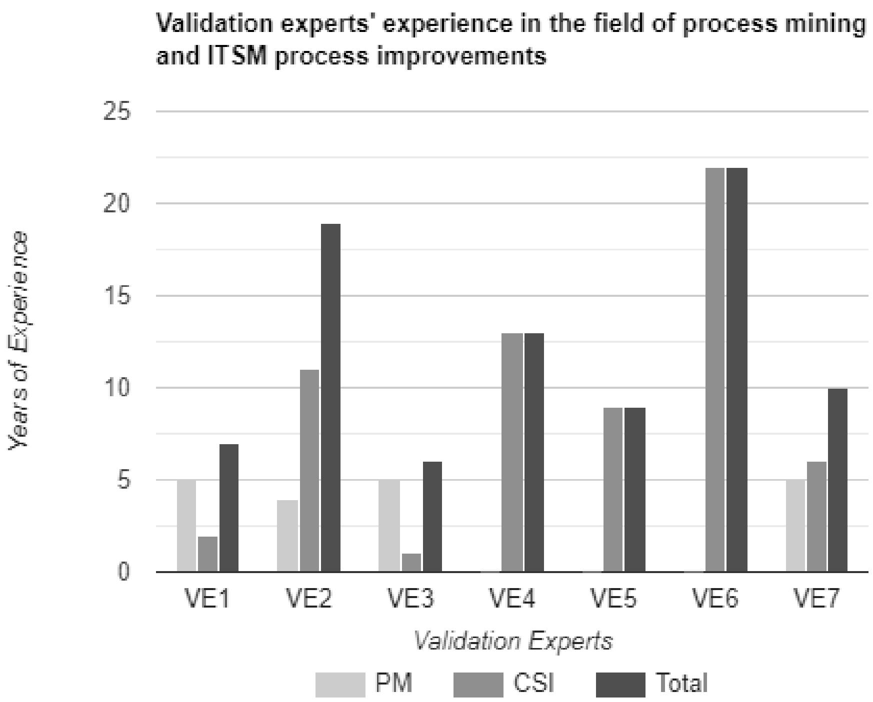

Figure 7.2: Evaluation Interview Participants' experience in years
Abbreviations used: PM- *Process Mining*; CSI- *Continual Service Improvement (ITSM process improvements); Total- Professional Business IT Experience*

7.2.2 Interview Protocol

The evaluation interviews, which were the first episode of validation research, consisted of two parts. A demonstration and discussion of the refined version of PM4CSI to the interviewees, followed by asking questions regarding the validity, relevance, usefulness, ease of use, and practicality of PM4CSI. First, the guideline was discussed as shown in Figure 6.1, with a short

Evaluation Construct	ID	Statement	Avg.	Collective Avg.	Result
Perceived Usefulness	PU1	I found the seven steps of ITIL Continual Improvement Model well integrated with the process mining approach (Relevance)	4.14	4.11	Agree
	PU2	I think that PM4CSI guideline supports organizations that adopt ITIL Continual Improvement model to more efficiently and effectively perform their activities with the help of process mining techniques.	4.14		
	PU3*	The way that the guideline shows 'how and when process mining technology can be used to support Continual Service Improvement activities' would be difficult for users to understand*	3.29		
	PU4	Using the guideline to communicate 'how and when process mining techniques can be used to support CSI activities' would be easier than doing so without guideline	4.43		
	PU5	Overall, I find the demonstrated guideline useful	4.57		
Perceived Ease of Use	PEU1	Learning to use the guideline to support CSI-related activities with the use of process mining would be easy for me	4.14	3.8	Agree
	PEU2*	I find the guidelines unclear and difficult to understand*	4.29		
	PEU3	It would be easy for me to become skillful at using the guideline	3.43		
	PEU4	I think that I would need the support of a technical person to be able to use the PM4CSI	3.00		
	PEU5*	Overall, I find the guideline difficult to use*	4.14		
Intention to Use	ITU1	I would use this guideline in order to apply process mining techniques to more effectively perform Continual Service Improvement activities	4.14	4.07	Agree
	ITU2	I would intend to use this guideline in preference to another approach of using process mining techniques to more effectively perform Continual Service Improvement related activities	4.00		

Table 7.2: Survey statements and corresponding results based on perceived usefulness, perceived ease of use and intention to use PM4CSI; The scoring range for analysis of the five-point Likert scale survey was calculated as follows: (1) Strongly Disagree: 1.00-1.80 (2) Disagree: 1.81-2.60 (3) Neutral: 2.61-3.40 (4) Agree: 3.41-4.20 (5) Strongly Agree: 4.21-5.00 **Note:** Responses are reversed for statement indicated with an asterisk (*)

explanation of how to interpret and the activities' flow discussed briefly. Addditionally, the activities required input and stakeholders, and output was discussed as shown in Table 6.1. After discussing all parts of PM4CSI, questions were posed to the interviewees to determine if anything was missing, if the interviewees thought the PM4CSI was beneficial if it was simple to comprehend, and if they would want to use it in the field. Then, the participants filled a survey to gather their opinion on the utility, usability, and intention to use PM4CSI. Out of the seven interviewed experts, all completed the survey, yielding a participation rate of 100%.

To critically evaluate the PM4CSI framework, survey questions were designed based on the constructs of the Technology Acceptance Model (TAM) [92]: Perceived usefulness, perceived ease of use, and attitude towards using, which evolved as an intention to use in TAM2 [21]. TAM has been adopted widely in the Information Systems field and has proven its validity through many previous studies [93, 94, 95].

The term *"perceived usefulness"* refers to how the user perceives the value of the PM4CSI in terms of its capability to benefit the user [21]. The degree to which a person thinks using PM4CSI would be effortless is known as perceived ease of use [21]. The two components mentioned above determine the intention to use, which is the extent to which a person intends to use the designed artifact [21]. The survey statements can be found in Table 7.2. These constructs were opted for, as one of the artifact objectives relates to these constructs in the sense that a ITSM practitioner should be able to use the framework conveniently whilst assessing and improving the service operations using continual improvement practice. To identify the level of agreement with each statement regarding the evaluation criteria, a five-point Likert scale, with options as strongly disagree, disagree, neutral, agree and strongly agree. Few of the survey statements, denoted with an asterisk (*), were negated to avoid monotonous responses [96].

7.2.3 Qualitative Analysis

The transcripts of the interview minutes were analyzed by reading, quoting, categorizing the collected data and corroborating the evidence. Initial codes were the evaluation criteria, and additional codes were used for data collected outside the criteria. Since the statement was tailored to the evaluation criteria, the coding and interpretations were valid and mostly straightforward.

7.2.4 Expert Validation Interviews' Results and Discussion

The refined version of PM4CSI, comprising of a high-level visual diagram (refer Figure 6.1), detailed overview of the PM4CSI framework (refer Figure 6.2), PM4CSI characteristics table (refer Table 6.1), and each phase with explanatory tables (Refer Table 6.2 to 6.9), has been demonstrated to both process mining and ITSM experts. Feedback gathered from the experts by demonstrating the PM4CSI framework through interviews was valuable in assessing the validity of the approach adopted. This section will present the evaluation results with quotes from the interview minutes. Figure 7.3 illustrates the experts' responses on the survey statements corresponding to the three constructs and the results indicating the experts' optimistic view towards the three constructs, i.e., PU1-PU5: perceived usefulness, PEU1-PEU5: perceived ease of use and ITU1&ITU2: intention to use.

General remarks on the framework

The general remarks on the PM4CSI framework were mainly based on the experts' opinions regarding the framework's limitations and purpose. The accuracy and completeness of the PM4CSI framework has been discussed during and after the demonstration of PM4CSI components. Most of the additions or changes suggested by experts were minimal modifications.

"It's quite an interesting topic. I never thought about this. That's already a good thing."

The level of granularity for the PM4CSI was agreed to be acceptable by all seven interviewees (*Requirements - Relevance and Comprehensiveness satisfied*)

"To be honest, the overview of the framework and the level of detail seem good. Maybe a point of improvement is to denote it in normal notations. I understand BPMN and can relate to it. It would be challenging for someone who does not understand BPMN concepts without reading the description that comes with the framework."

The favorable response to question PU1 by the ITIL and process mining experts also reflects on the satisfaction of requirement: Relevance, as stated in Table 2.

Perceived Usefulness

The experts of the validation interviews agreed that a standardized methodology stating operational aspects as presented in the detailed overview of the PM4CSI framework is useful to guide ITSM practitioners effectively perform continual improvement practices by leveraging the process mining technology.

"It is always easier with a framework, so I will strongly agree"

"Process Mining is a new concept, at least for me, and having an operating model will be really useful because it guides with when and how to use process mining techniques and with what kind of expertise for successful improvements"

"Structure and predefined framework of using process mining into CSI (continual service improvements) practices will benefit the ITIL process owners. How process mining could contribute to service improvements is convincing. So, I think it has great utility with the data underlying these service operations."

Overall, the experts considered the designed framework to be useful. The statement PU2 directly reflects the goal of this research. All experts (strongly) agreed that PM4CSI would support organizations adopting ITIL continual improvement practices to perform the improvement initiatives leveraging the process mining techniques effectively. However, two experts indicated that it would be difficult for users to understand with little or no expertise in the domain.

Perceived Ease-of-Use

The response of the experts also stated that the PM4CSI framework was easy to use. Nevertheless, the experts mentioned that complexity is needed to capture detailed application of the process mining techniques in continual service improvements.

"I do not find the framework difficult to understand or would find it difficult to be used in practice. But if you would have to give this framework to someone with no expertise in either process mining or ITIL, they would find it difficult. But definitely, provided the conceptual knowledge of the domain and data-driven improvements, I strongly disagree. I don't find it difficult to use"

"So I would agree. it's just like it can strongly agree with me having to read a little bit maybe on the process, but you know, I can do with your thing, and you know, checking a few things which you know, just to have a little bit more background to I think I can for me. I could say this strongly. I could see myself doing this after looking into the explanatory part; I think I agree with how easy it is for me to use the framework"

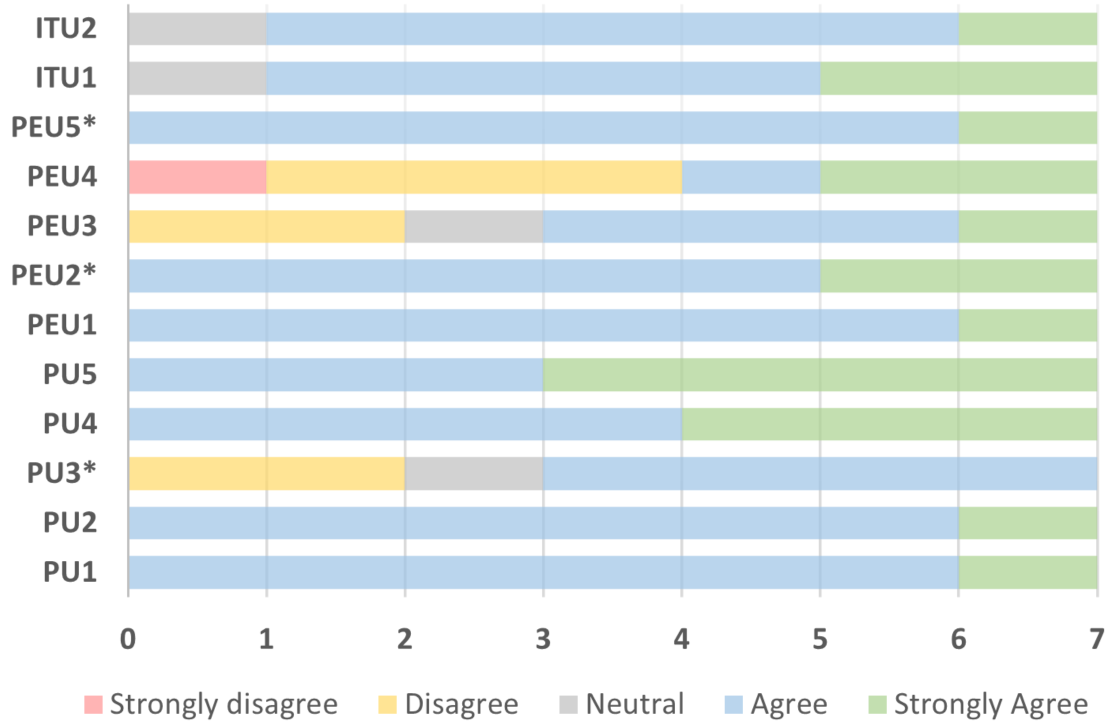

Figure 7.3: Experts' responses for the survey statements from Table 7.2; Note: Responses are reversed for statement indicated with an asterisk (*)

"If I am learning to use it, it would be helpful to understand, but sometimes, it is a little bit high level for me. For a starting point, it is very good"

"I would not do this without a technical person next to me"

"If this was a tool-driven approach, then yes, but with an unsupported application point of view, I would disagree with the need for a technical person"

However, experts with no experience in the field of process mining insisted on the support of a technical person to understand how the process mining techniques can be used in ITSM process improvements. Overall, the survey on 'perceived ease-of-use yielded a positive attitude.

Intentions to use

The experts firmly intended to recommend the PM4CSI framework to ITIL practitioners for service improvements. Also, it has been mentioned by an expert if the 3P's, as shown in Figure 3.13 are in place, then the expert would strongly intend to follow this framework.

"I think on the positive, I think agreeing will be okay. So if it comes in handy or a possibility or the people are good enough, mature enough, understand enough, then yeah, this would indeed be a thing to do and otherwise and don't do it at all."

There were positive responses for the intention to use PM4CSI to improve service processes using process mining techniques. Three of the seven experts mentioned a neutral response to ITU2, as they are unaware of any other approach similar to the PM4CSI.

"With such a structured way of doing CSI using process mining techniques and how process mining is complementing the Continual Improvement practices, I think it's definitely no brainer to use the PM4CSI, given there are no such methodology in place at this point within

our department."

I currently work under my own practice and find similarities of the framework with my approach. Thus, I would definitely recommend the intention of PM4CSI for service improvements.

7.3 Case studies

The second episode of validation consists of case studies. This section describes how PM4CSI was applied in concrete case studies to test the PM4CSI framework in a naturalistic setting. The case studies have been conducted with three process mining tools, Microsoft Process Automate (integrated with Minit), Celonis, and Process X-ray.

7.3.1 Case Study Participants

The first case study was conducted with a public dataset to use the PM4CSI framework using Microsoft Power Advisor tool. The second case study was with an organization that wanted to improve its incident management process, the functional beneficiary of the PM4CSI framework. The organization chosen was selected to represent typical Deloitte Enterprise Service and Process Management customers: large companies with enormous amounts of process-related data. Each case study consisted of meetings with the relevant stakeholders and follow-up meetings to discuss and deliver accurate results.

7.3.2 Case study protocol

The researcher followed the PM4CSI framework during the case studies. The goal of the case study is twofold: (i) to test the functional requirements (Section 2.2), (ii) to test the evaluation criteria or the non-functional requirements of the designed artifact, PM4CSI. The following protocol was used for the case studies of this research.

- *Selection:* Case study entities were selected based on their capabilities in terms of people and process data instances. If the participants lacked standardized workflow implementation or relevant people suggested by the framework, they were requested to snowball suitable case study candidates.
- *Preparation:* Potential participants were presented with the information regarding the research and the artifact over online meetings set up with the help of the Deloitte People Network and through a snowballing approach during the framework refinement expert interviews.
- *Implementation:* Follow the PM4CSI framework to improve the service operation using process mining techniques offered by multiple market vendors with the data acquired.
- *Documentation:* Preparing documentation of the execution of the case study conducted.

7.3.3 Case 1: Public Data - Microsoft Process Automate

Case study 1 was an open data case study carried out with an enriched event log from an incident management process extracted from the audit instance of a ServiceNow™ platform used by an IT company. The event log contained information regarding the transactional data in which the incidents are organized based on the lifecycle of the incidents. The event log consisted of 141,712 events (instances) and 36 attributes corresponding to 24,918 unique incidents between March 2016 to February 2017. The publicly available enriched event log[1] was downloaded as a flat file. Due to the numerous attributes connected to the incidents, it is regarded as an enriched

[1]Dataset link: UCI Machine Learning Repository-Incident management process enriched event log Data Set

1	number	incident identifier (24,918 different values);
2	incident state	eight levels controlling the incident management process transitions from opening until closing the case;
3	active	boolean attribute that shows whether the record is active or closed/canceled;
4	reassignment_count	number of times the incident has the group or the support analysts changed;
5	reopen_count	number of times the incident resolution was rejected by the caller;
6	sys_mod_count	number of incident updates until that moment;
7	made_sla	boolean attribute that shows whether the incident exceeded the target SLA;
8	caller_id	identifier of the user affected;
9	opened_by	identifier of the user who reported the incident;
10	opened_at	incident user opening date and time;
11	sys_created_by	identifier of the user who registered the incident;
12	sys_created_at	incident system creation date and time;
13	sys_updated_by	identifier of the user who updated the incident and generated the current log record;
14	sys_updated_at	incident system update date and time;
15	contact_type	categorical attribute that shows by what means the incident was reported;
16	location	identifier of the location of the place affected;
17	category	first-level description of the affected service;
18	subcategory	second-level description of the affected service (related to the first level description, i.e., to category);
19	u_symptom	description of the user perception about service availability;
20	cmdb_ci	(confirmation item) identifier used to report the affected item (not mandatory);
21	impact	description of the impact caused by the incident (values: 1-High; 2-Medium; 3-Low)
22	urgency	description of the urgency informed by the user for the incident resolution (values: 1-High; 2-Medium; 3-Low)
23	priority	calculated by the system based on 'impact' and 'urgency';
24	assignment_group	identifier of the support group in charge of the incident;
25	assigned_to	identifier of the user in charge of the incident;
26	knowledge	boolean attribute that shows whether a knowledge base document was used to resolve the incident;
27	u_priority_confirmation	boolean attribute that shows whether the priority field has been double-checked;
28	notify	categorical attribute that shows whether notifications were generated for the incident;
29	problem_id	identifier of the problem associated with the incident;
30	rfc	(request for change) identifier of the change request associated with the incident;
31	vendor	identifier of the vendor in charge of the incident;
32	caused_by	identifier of the RFC responsible by the incident;
33	close_code	identifier of the resolution of the incident;
34	resolved_by	identifier of the user who resolved the incident;
35	resolved_at	incident user resolution date and time (dependent variable);
36	closed_at	incident user close date and time (dependent variable).

Figure 7.4: Data description of event log used in Case study 1

event log. Since it contains events with the same value in all variables except the date element, its contents openly reflect some of the information that identifies the company's incident process and implicitly implies the existence of various behaviours in the process. Figure 7.4 shows the description of the data attributes of the incidents present in the enriched event log.

With the acquisition of the famous process mining tool *Minit*, Microsoft released the process and task mining capabilities through Process Advisor included in their Power Automate platform. This case study is based on process mining analysis using the *Process Advisor* feature from the *Microsoft Power Automate platform*. The Process Advisor contains the latest developments in the process mining research, and access to the tool was available upon request to the Microsoft Power Automate Team. The following will present the activities executed in each stage of the PM4CSI.

Execution

An overview of the activities of *Case Study 1* is shown in Figure 7.5. It also shows where the case study encountered issues or deviated from PM4CSI.

1. ***Project Initiation***
   In the context of available open data, a mock session of the *Project Initiation* phase was designed and conducted by the researcher. An informal session was conducted with an ITSM practitioner to understand the process associated with the available event log. During the mock session, the project vision and the scope of the process mining project were also defined. The vision of the case study project was to successfully implement process mining analysis using the guideline provided by PM4CSI. The project scope

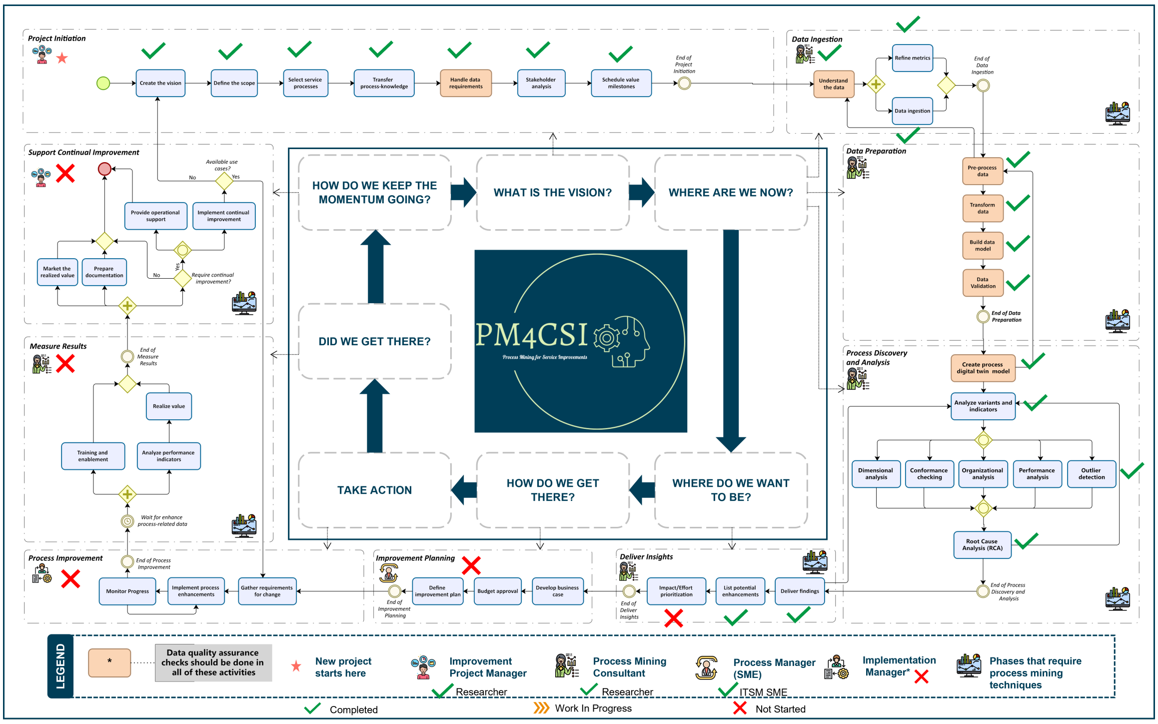

Figure 7.5: An overview of the case study execution corresponding to the phases of PM4CSI

was to perform an exploratory process mining analysis to test the capabilities of process mining in an ITSM sphere, which strategically aligns with the vision. Due to the nature of the case study being an open-data case study, the stakeholders involved during this phase only included the ITSM practitioner (as *process owner*) and researcher (as *process mining analyst and IT data source system admin*). Then, data quality was analyzed since the data was obtained from a publicly available database. Most of the dimensions of the enriched event log contained empty values, which showed poor-quality data from the perspective of decision point analysis (refer 3.1.5) due to missing entries. The process mining project milestones were communicated during this phase. Finally, the first phase concluded with scheduling the meeting for the case study progress to obtain value at each milestone.

2. ***Data Ingestion***
   The enriched event log was understood based on the data description and the process explained by the assigned process owner in the previous phase. Based on the data, the operational level of KPIs was identified during this stage. Since Case Study 1 deals with open data, data ingestion was done by uploading the enriched event log flat file into the Process Advisor. Figure E.1 in Section E.1 of Appendix E shows the data ingestion routes provided by Microsoft Process Advisor.
3. ***Data Preparation***
   During this phase, the data was cleansed based on the missing values and entries with the unsupported format. Specific transformation queries were executed to modify the timestamp format within the Process Advisor tool. The data mapping was skipped since the extracted file was just a single and an already enriched event log. Case-level attributes and event-level attributes were identified, as seen in Figure E.2 from Section E.1 of Appendix E. Then a process-data model was created. Finally, a data validation step was conducted to verify the quality of the data prepared for the process mining analysis.
4. ***Process Discovery and Analysis***
   Based on mapping case level and event level attributes, with the specification of case

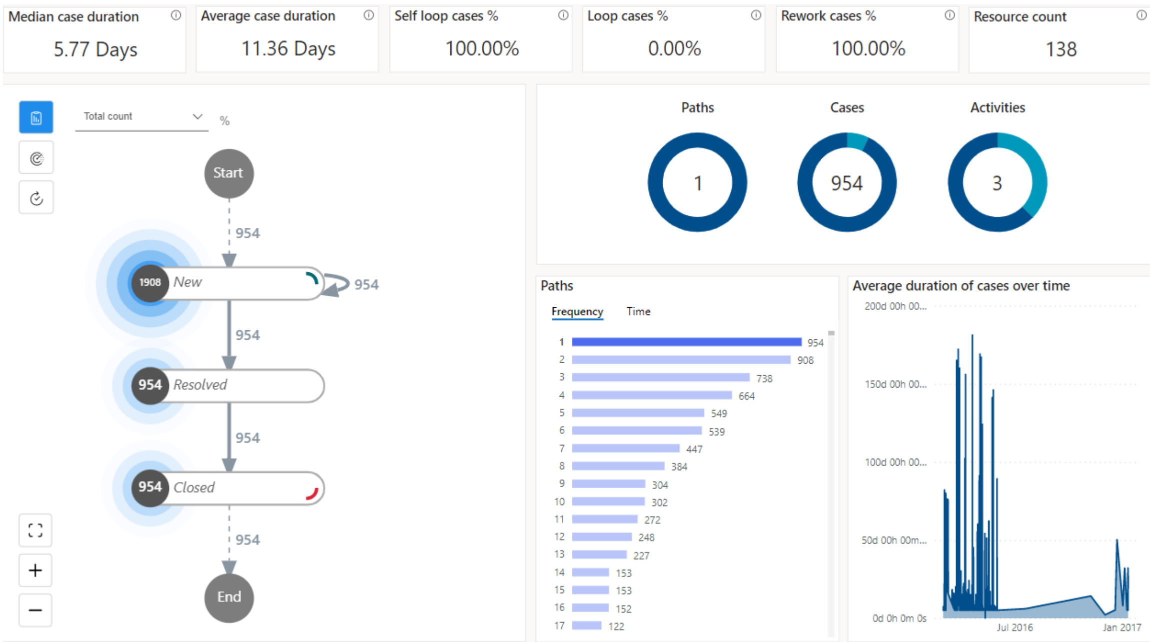

Figure 7.6: First Glimpse of Process Explorer using Process Advisor
The left section shows the discovered process using process mining techniques; the 'Paths' section shows the number of cases in each variant which can be filtered, and other single dimensional indicators

ID, activity, and activity timestamp, the Process Advisor generates a process flow model automatically with built-in process discovery algorithms. Figure 7.6 shows the initial glimpse of the process, and Figure 7.7 shows the complete connections of the activities found from the uploaded process data. Figure 7.6 depicts the most frequent variants having the path New –> Resolved –> Closed. Such insight could mean certain missing activities due to a lack of data, inefficient workflow implemented in the system, or poor operational practices. It also shows that the duration of cases for most common process variants has drastically reduced over the last year, signifying a potential bottleneck being resolved. The process variants are analyzed as shown in Figure E.3, and various functions for metrics analysis are checked to check the correctness of data uploaded for the process analysis. Variant analysis depicted that most top process variants differ by less than two activities, primarily through self-loops. A combination of process mining analysis, such as dimensional analysis and performance analysis, has been conducted to answer the efficiency aspect of the process in question. The snapshots of the performance and organizational analysis can be found in Appendix E through Figures E.4 and E.5. Then, root cause analysis was performed by involving the assigned process owner for directions and guidance on relevant analysis. The question 'Why self-looping paths are identified' were analyzed by performing process mining analysis on the self-loop net gain metric as shown in Figure 7.8.

5. ***Deliver Insights***
The insights found using the process mining analysis were presented to the assigned process owner. The potential improvement areas were discussed. However, the case study ends with this activity due to the need for more access to tangible services associated with the data for process improvements. Thus, ***Improvement Planning***, ***Process Improvement***, ***Measure Results***, and ***Support Continual Improvement*** were not performed during this case study.

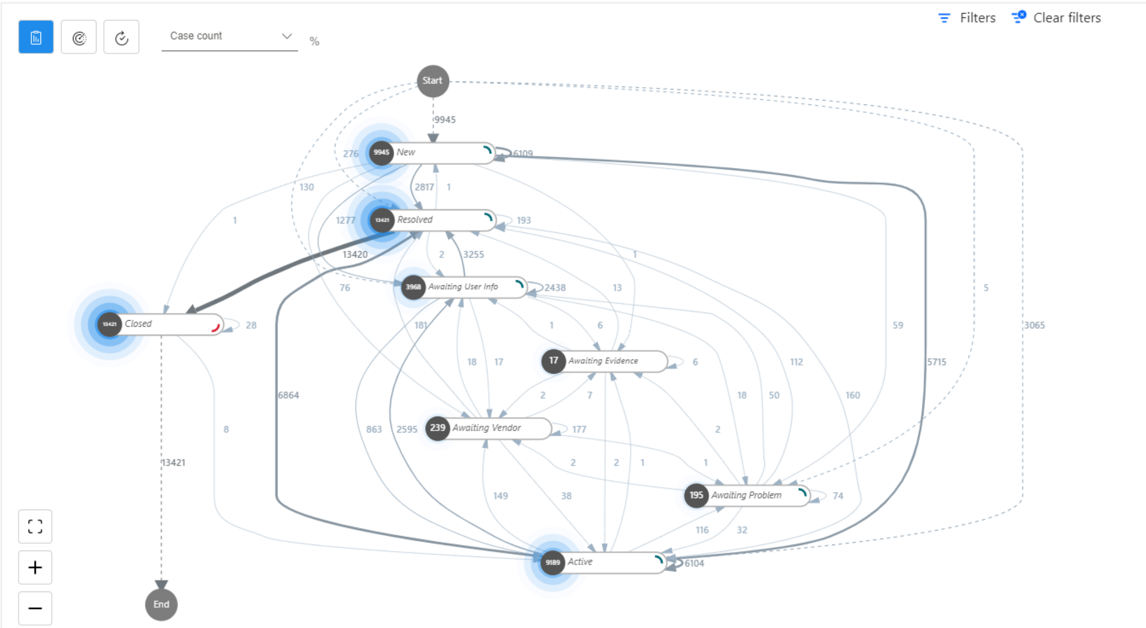

Figure 7.7: Overview of connections between events

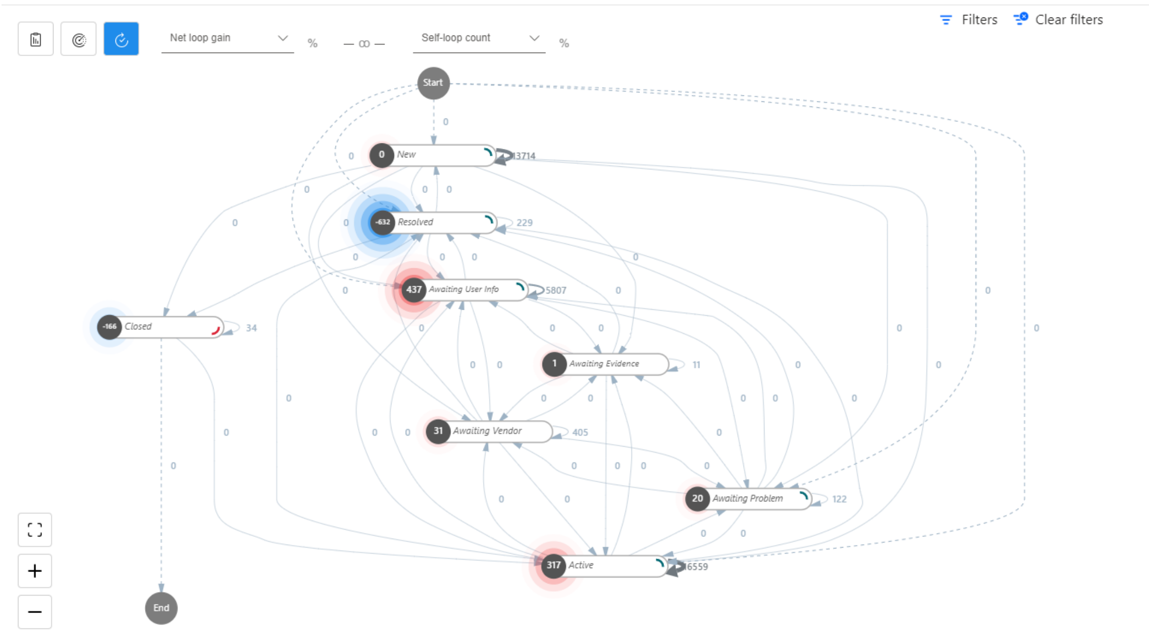

Figure 7.8: Overview of events contributing to self-loops within the process flow

7.3.4 Case 2: Leading Medical Imaging Equipment Supplier

The case study was conducted at an organization here called ABC, a leading medical imaging equipment supplier. Among many other services, ABC provides customer service for their solutions. The key ITIL operations include change management, incident management, and problem management (see Table A.1). These operations are supported by a service management platform known as *Vivantio*. In this research, the incident management process was analyzed. The process starts with customers raising incidents through three different portals and ends when the customer agrees to the resolution provided by the support team. A confidentiality agreement was implied in this particular case study. Consequently, some confidential information, including data, flow charts, process scope and metrics, and process discovery diagrams, have been omitted and not mentioned explicitly here.

For our case study at Company ABC, two process mining tools from the market were chosen, namely Celonis and Process X-ray, to support applying the PM4CSI framework. Both the tools were available on a special request for a sandbox environment. In the following, we shall discuss the activities executed during *Case Study 2* and the process mining analysis results.

Execution

An overview of the activities of *Case Study 2* is shown in Figure 7.9. It also shows where the case study encountered issues or deviated from PM4CSI.

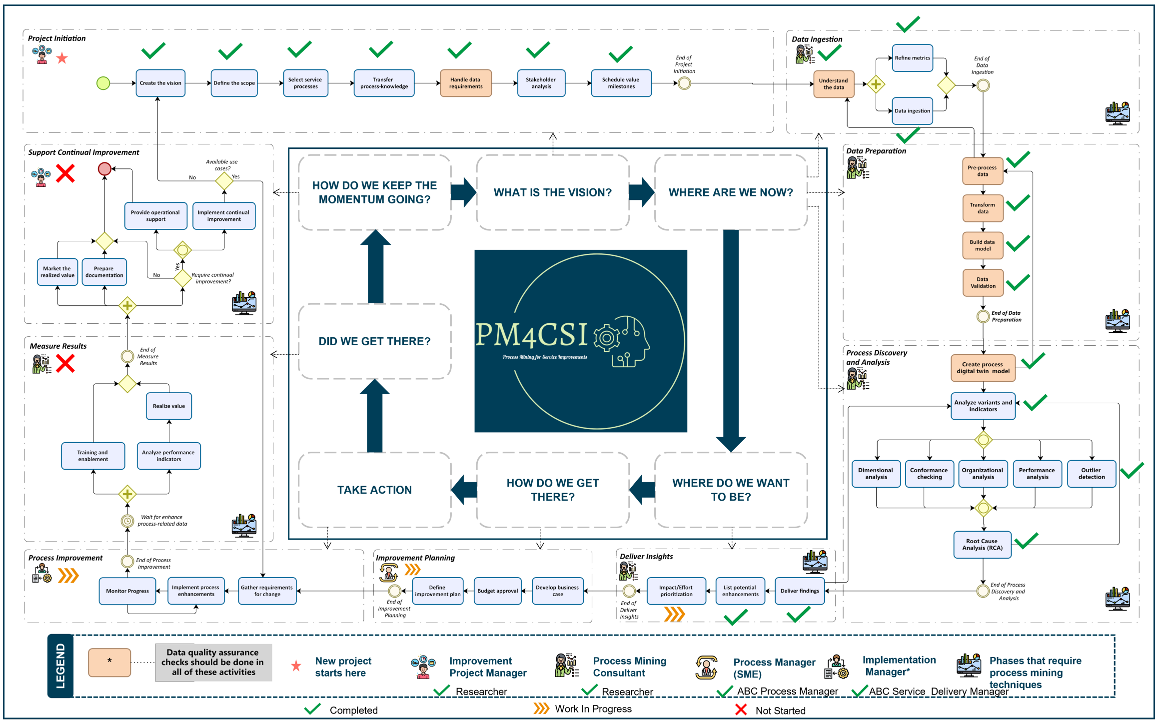

Figure 7.9: An overview of the case study execution corresponding to the phases of PM4CSI

1. ***Project Initiation***
   Three separate sessions were conducted with the process owner and master data owner to complete this phase and successfully kick-start the process mining improvement project at ABC. The first session covered an explanation of the PM4CSI framework, followed by creating the vision, defining the scope and selecting the service process to be improved by identifying the problem areas. The main business question was to reduce the flow of incidents, which would make their problem management easier to handle, given limited

support team members. Since the contract for the case study with the company was initiated by the Chief Financial Officer (CFO) of the department, the commitment of business leadership was ensured. Additionally, confidentiality documents were signed by the researcher to ensure data access. The second session included transferring process knowledge and acquiring workflow documents with process notations. Additionally, the scope of data for analysis of the problem areas was derived. The KPIs were defined by the process owner during this session. Based on the understanding of the process, figure 7.10 was created in the Bizagi modeller to illustrate the incident management process at ABC. During the third session, the data owner confirmed data availability corresponding to the focused service process. The data associated with the process and identification of systems tracking all relevant data columns were discussed. Additionally, the milestone for the process mining project has been discussed to deliver value on time. During all of the sessions, the main aim was to focus on the objectives to generate value in future and be strategically aligned with the organizational goal, which the involved stakeholders appreciated for a value-driven approach.

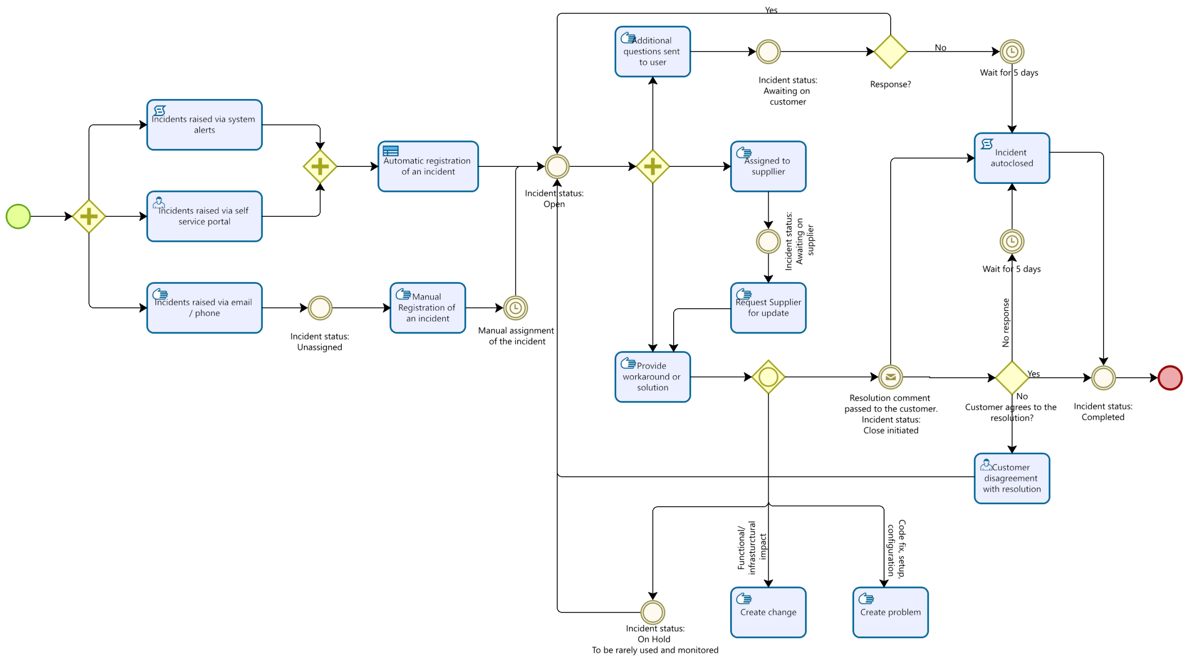

Figure 7.10: Incident management process at ABC represented as BPMN

2. ***Data Ingestion***

The data owner presented the data columns and the workflow associated with the data in sight. During this session, the data attributes, their relationships with each other, and the process were understood. The data extraction window was agreed upon by the process owner, process analyst (researcher) and data owner between April 2022 to November 2022. Certain KPIs identified during the previous phase had no relevant data, which will be challenging to measure and manage. Thus the KPIs were refined and communicated with the process owner and data owner for seamless and accurate process mining analysis. Company ABC wanted to try executing the process mining project to oversee and trust the value of service improvement using process mining techniques. Moreover, a dynamic data connection to Vivantio and associated information systems would require an upgraded license of the process mining tools and more information security clauses to be signed off, which is a constraint for the duration of this research. Thus, a one-time solution

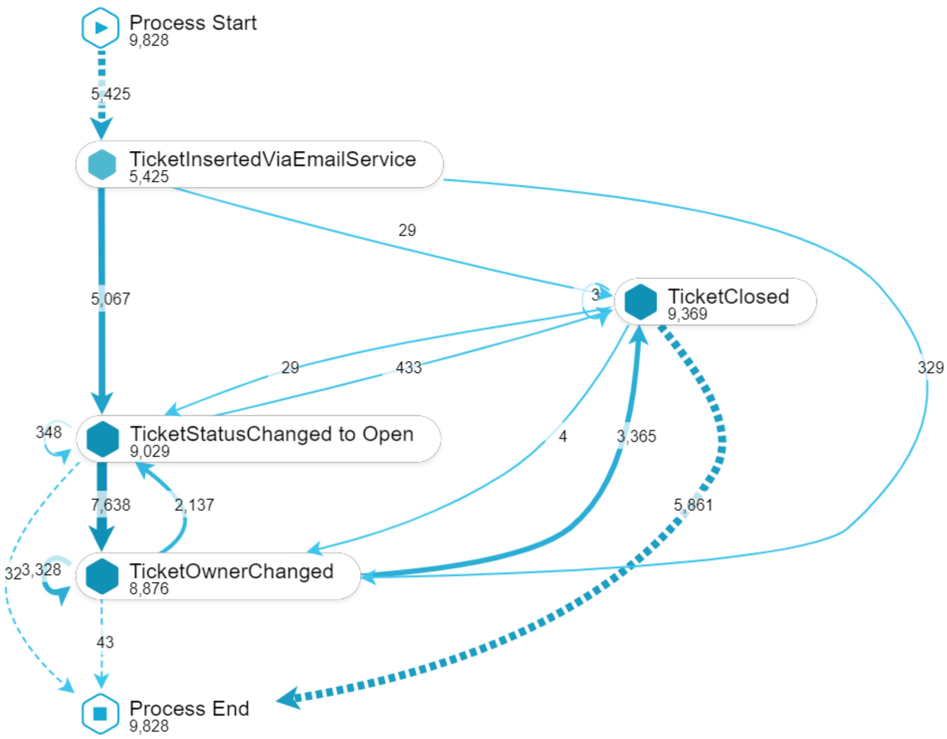

Figure 7.11: Discovered process through Celonis Tool

was suggested, leading to data ingestion by uploading a flat file. The data owner took responsibility for extracting data from the associated information systems. The files were received as a CSV file with field separators as '|'. The files were uploaded to the Celonis tool directly. However, for uploading the file to Process X-ray, the data preparation phase happens outside the tool; hence, the enriched event log was uploaded to Process X-ray after performing the activities of the next phase.

3. ***Data Preparation***
Upon the first glimpse of data, specific data quality issues were found, as mentioned in Table 6.3, which required immediate attention. The critical issues with data quality included: Low level of abstraction of events, missing data entries for essential attributes such as the category of tickets, inconsistent timestamps due to different methods of incident registration in Vivantio and a low level of DateTime format correctness.
   (a) *Celonis*: Firstly, the data preparation was done using the process mining tool. The data was cleansed using Vertica SQL queries within the Data Integration tab of the Celonis tool. Then transformation queries were scripted to prepare an enriched event log with additional data columns for process mining analysis. Then, process data models were created following a star schema to represent relationships between the tables and perform redundancy checks on the data columns. Foreign keys were assigned to connect the tables. The data quality was again validated with the data prepared during this phase. Then, the process data models were loaded into the Celonis platform for process mining analysis in the Celonis studio.
   (b) *Process X-ray*: Next, for preparing the data for Process X-ray tools, the same data quality issues were fixed by a data engineer using Python scripts. The process data were joined into a single table. The enriched data file were uploaded to the Process X-ray tool, where the mapping for the data columns was provided by uploading a data description file to the tool.

4. ***Process Discovery and Analysis***
   (a) *Celonis*: The tool automatically discovers the process flow diagram, which is first analyzed to see if the expected data flow is visible for process mining analysis. Due to the issue of low-level abstraction of events in data, there was an iteration back to *data preparation* activity. Thus the data was validated again while creating digital twin process models. Once the expected attributes of process flow were set, the process's variants and indicators were analyzed. Conformance checking was suggested, but the ABC was more interested in the process flow, performance and other dimensional analysis. The process owner was communicated with the direction of the analysis, and feedback was received for finding potential value out of the process mining analysis. Figure 7.11 shows a sample variant of the process discovered using Celonis.
   (b) *Process X-ray*: As similar to Celonis process mining analysis, Process X-ray offers the discovery of a process flow diagram with variant analysis as patterns inspection. The processes were analyzed based on different dimensions, such as the category of tickets, efforts taken by the support team, and escalation status. Figure 7.12 shows a sample variant of the process discovered using Process X-ray.
5. ***Deliver Insights***
   The insights based on the value and objective of the case study were delivered to the process owner and a process user over an online session. A list of potential use cases for improvements was identified. The process owners are interested in further analysis.
6. ***Improvement Planning***
   At the time of writing, this phase is still ongoing. The process owner was interested in further process mining analysis of different aspects of the process.
7. ***Process Improvement*** At the time of writing, discussions were also kick-started to implement the suggested operation improvements based on the valuable insights derived from the process mining analysis
8. Due to time constraints of this research, the following phases: ***Measure Results***, ***Support Continual Improvement*** will not be documented in this report.

7.3.5 Case Study Discussion

This section presents the lessons learnt from and challenges encountered during the case studies.

The consequences of applying the PM4CSI framework during the case studies are that a project team can successfully execute the continual improvement initiative using process mining techniques. Additionally, the process mining analysis has generated more concrete process improvement ideas.

During case study 1, since the execution was conducted with an enriched event log which was available as open data, the data ingestion phase was through data uploads. However, the Project Initiation phase had to be back-traced by conducting a mock initiation session with an ITSM expert to understand the process associated with the data in depth. During the data preparation phase, queries were scripted within the Process Advisor tool, and process mining analyses were performed. Since this was an exploratory case study, the ITSM practitioner was involved in online meetings to create concrete business questions based on analyzing the process-related data. One significant finding from this analysis was to understand the process mining tool's capabilities by checking what the tool provides out of the box. Process advisor focused on providing automation. Consider the organizational data incorporated in a Microsoft storage. With an azure license, it is better to integrate with Microsoft Power Solutions from a

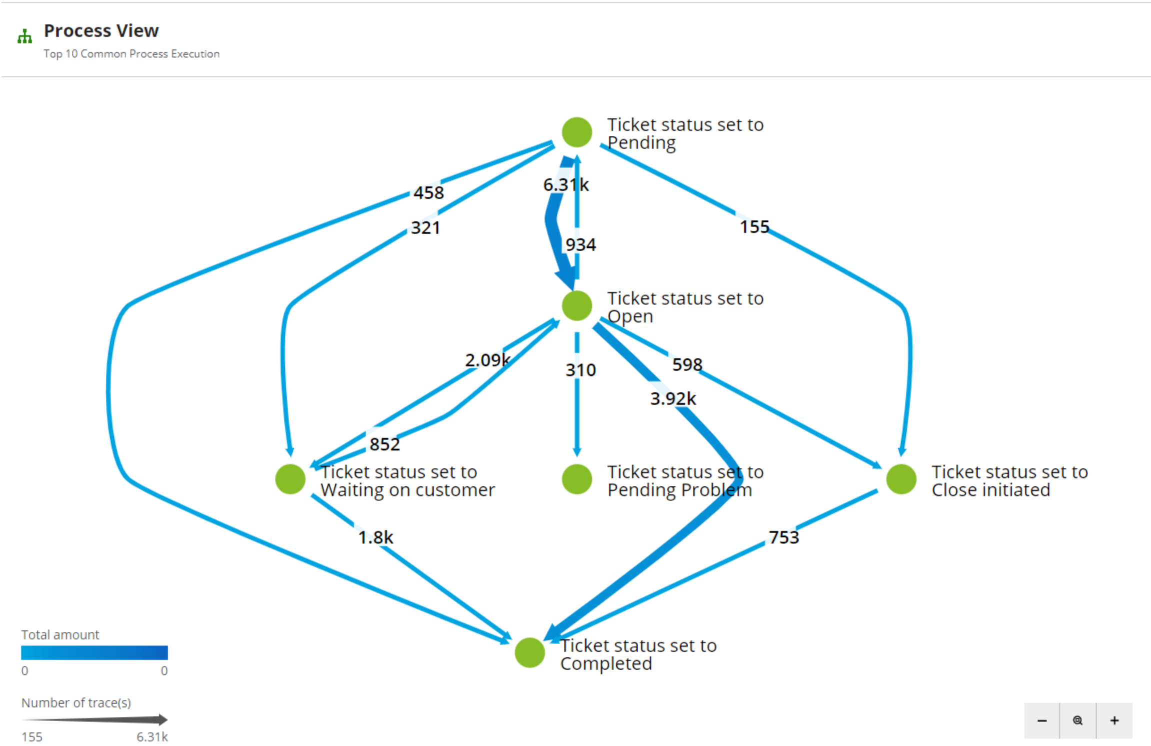

Figure 7.12: Discovered process through Process X-ray Tool

monetary perspective. However, Process Advisor is limited in providing out-of-the-box root-cause analysis. Hence as mentioned in the PM4CSI guideline, if the data was associated with a real-world problem context, then as suggested by PM4CSI framework, it is essential to consider the hybrid intelligence for the Root-Cause Analysis phase.

During Case Study 2, with the nature of the case study being a single-case mechanism experiment, the data was associated with a real organization's ITSM process, i.e. incident management process. One of the significant challenges encountered during *Project Initiation* phase was to schedule the value milestone due to the dynamic nature of the stakeholders involved. Also, while using Process X-ray, the data was accounted to *Data Preparation* phase, right after data understanding and before ingesting the files into the Process X-ray. Although, with Celonis, the PM4CSI framework was executed as per the design. Arguably, even with Process X-ray, the sequence of activities was mixed only within *Where are we now?* phase, which does not cause many deviations to the activities desired as per PM4CSI. One of the key challenges during the data preparation phase was with the timestamps. The timestamps relating to every activity were a mix of 12/24 hour format and varying data format (as ddmmyyyy and mmddyyyy). Most of the time during data preparation was spent transforming the DateTime column to a single and accurate format. Also, there were missing data entries for which data manipulation queries have been executed to get as accurate data as possible.

New research questions while identified during the *Root Cause Analysis* activity and during the *Deliver Insights* phase, which caused iterations to the start of the *Process Discovery and Analysis* phase. However, PM4CSI also allows such iterations, which was an expected route during the case study. As other studies claim, any process mining initiative can succeed if and only if the business process experts and analysts collaborate iteratively. The initial round of process analysis during both cases lacked in-depth domain knowledge leading to less impactful insights. Collaborating with the process experts and process users, and working holistically led to faster and more relevant analysis and tangible process improvement ideas. It would be even more beneficial if the business users were trained with the basic conceptual understanding of process mining before the process mining improvement initiative, which is a lesson from ABC during the case study.

7.3.6 Case Study Validity

The data for these case studies are supplied without the researchers' involvement. *Case study 1* has been conducted using open data available at a public data website. Direct access to the data has not been provided to the researcher during *Case study 2* to prevent unintended information security issues. Throughout the data extraction phase, an intermediary carried out the data gathering activities, which could be the reason for identified data quality issues during both case studies. Therefore, the insights due to process mining analysis could be because of missing accurate data in the extracted files. The major challenge identified during the *Case Study 2* is that after the *Deliver Insights* phase, the researcher had to wait until the stakeholders were aligned to a timeslot to discuss further plans for improvement. Whereas in the *Case Study 1*, open data from a public data repository was used to validate the framework using Process Advisor. Due to time constraints, every phase of PM4CSI has not been able to be documented at the time of this writing, which could threaten the validity of PM4CSI framework. However, the case study was mainly conducted to validate the Tool Independent nature of the PM4CSI. Other requirements were collaterally satisfied during this case study, such as relevance, showing that the steps are relevant to both the domain, comprehensiveness, showing all the domain activities are involved, utility showing the framework is useful for applying process mining techniques to improve ITSM processes and usability, the framework being easy to apply in practice.

7.4 Summary

- The mixed-method validation strategy has been adopted to validate the framework, PM4CSI V1.0. Two episodes of validation, namely *Expert Opinions* and *Case Studies*, were conducted during this research to check if the specified requirements have been satisfied.
- Firstly, interviews with seven domain experts have been conducted to gather their opinions on the PM4CSI V1.0. To critically evaluate the PM4CSI V1.0 framework, survey questions were designed based on the three constructs of the Technology Acceptance Model 2 (TAM2): Perceived Usefulness, Perceived Ease of Use, and Intention to Use and eliminating the monotonous responses by negated statements. Table 7.2 shows the survey statements and results corresponding to the chosen evaluation constructs.
- Expert Opinions served as a validation strategy to satisfy requirements such as relevance, comprehensiveness, usability, and utility. The results and discussion of the expert opinion validations process have been discussed in section 7.2.4.
- Secondly, case studies have been conducted with three process mining tools, namely Microsoft Process Advisor, Celonis, and Process X-ray, with publicly available data and data from an organization, a leading medical imaging equipment supplier.
- Case study validation strategy has been adopted to primarily satisfy the tool-independent nature of the framework besides satisfying other requirements such as usability, utility, relevance, and comprehensive guidelines.
- Case studies revealed that a project team could successfully execute the continual improvement initiative using process mining techniques. Additionally, case studies showed that it is essential for business users to be trained with a basic conceptual understanding of process mining for better facilitation of the improvement project. The data preparation

phase came before the data ingestion phase using the Process X-ray tool. However, the activity remained mapped to the second step of ITIL Continual Improvement model.

- Due to time constraints, every phase of the PM4CSI V1.0 has not been documented at the time of this writing.
- However, case studies validated the tool-independent nature of the designed framework. Other requirements were collaterally satisfied during this case study, such as relevance, showing that the steps are relevant to both the domain, comprehensiveness, showing all the domain activities are involved, utility showing the framework is useful for applying process mining techniques to improve ITSM processes and usability, the framework being easy to apply in practice.

Chapter 8

Discussion

The results of this research and its limitations will be discussed in this section. Section 8.1 describes the reflection on the research methodology. The discussion iterates over the steps taken to design the PM4CSI framework to leverage process mining techniques in Continual Improvement practices in section 8.2. Section 8.3 and 8.4 refers to recommendations to practitioners and Deloitte, respectively. The chapter concludes with the research's limitations and a review of possible future work.

8.1 Reflection on Chosen Research Methodology

The present research spread out by leveraging existing methodologies, guidelines and methods to develop the PM4CSI framework. The focus was more on the accurate and valid adoption of methodologies and guidelines rather than an ad-hoc guideline that should be defended for its validity. Consequently, it laid out a strong foundation, well thought-out, and validated approach throughout the development and evaluation of the PM4CSI framework.

The Process Mining for Continual Service Improvements (PM4CSI) was developed following Wieringa's Design Science Research Methodology (DSRM) [13]. DSRM aimed to evaluate the framework in a problem context concerning the stakeholders' objectives. Thus, the methodology is proven for its suitability to result in solid reflections on the effects of the artifact in the real-world context. A bottom-up approach was followed to determine the constructs of the framework designed in this research, i.e. by collecting existing practices, which ensured opportunities for brainstorming, constructive criticism, and feedback that frequently resulted in better methods and outcomes.

A mixed-method development strategy was adopted in this research. The literature review, including systematic literature review and semi-systematic literature review, ensures this research leverages and builds upon the existing scientific knowledge. Critical analysis of the relevant studies was conducted with an ad-hoc scoring scheme as explained in section C.2. Nevertheless, reviewing existing scientific knowledge solely lacks practical relevance to the gathered knowledge. Thus, experts were interviewed to identify the existing approaches of applying process mining in the context of ITSM process improvements. Consequently, a strong foundation was laid for combining the existing literature and empirical research by following a mixed-method development strategy.

The resulting PM4CSI framework was evaluated with a mixed-method validation strategy. Expert opinion as an evaluation method provided a simple evaluation by simulating the conditions of practices and rating the model based on set evaluation criteria. Nevertheless, such evaluation is artificial and includes only a few stakeholder groups. Case studies provided a more naturalistic method by simulating the conditions of practice by applying the framework during the continual service improvement projects at the case organization. Consequently, a valid evaluation strategy was followed to complement the shortcomings of both validation methods.

The case studies allowed the demonstration of the framework in a real-world context. The lack of time during the research revealed the primary setback of the case study as a choice of research evaluation method: the process improvement project depends on the commitment of the business users and leadership, which requires more duration than the theoretical calculation of project milestones. In a positive real-world problem context, an organization would apply the PM4CSI framework in the service improvement initiatives, which would be an improvement project ranging at least between 3-6 months for simple process improvements depending on the complexity of the process redesign. Given the sufficient time for the research, PM4CSI framework is expected to be most beneficial to carry out continual service process improvements using process mining technology. Despite such limitations, the researcher found the case studies as a valid evaluation strategy as they act as a realistic setting. Even though at the time of writing this report, the case studies did not complete the entire cycle of PM4CSI, the improvement projects are planned for the next few months., which is both valuable for evaluating the framework and adding value to the case organization. With considerable time and dedicated sponsorship for the improvement initiative, this case study would result in a Technical Action Research, where the effects of the application of the framework entirely can be studied [13]. Considering the maturity level of ITSM in the organization and time constraints, it is an obstacle to fast-track the project to complete the execution of all the phases of the PM4CSI framework. Hence, design science methodology was the appropriate viable methodology for all these reasons. With the commitment of the leadership and sponsor and adequate time, the researcher can observe the effects and then perform framework validation in a real-world context.

8.2 PM4CSI Framework Reflection

The current research resulted in process mining for continual service improvements framework, named PM4CSI. Seven field experts evaluated the framework regarding the relevance, usability, and usefulness evaluation criteria. Additionally, the case studies contributed to the evaluation of all the criteria set up at the start of this research project. Each criterion was rated *Agree* according to the five-point Likert scale analysis, indicating the fulfilment of the research's design goals. Nevertheless, critical reflection on the designed framework raises specific topics of discussion.

Firstly, the discussion of adding a data-driven approach to ITIL continual improvement practice requires an understanding of both process mining and ITSM domain. Otherwise, the framework would be difficult to be perceived in a business context. Based on these arguments, it is recommended to educate the ITSM stakeholders involved in applying the PM4CSI framework with the right kind of training resources to understand the concept of process mining before committing to the project. This is considered important as the success of process mining improvement projects depends equally on the availability of the right expertise as much as the availability of process-related event data.

Secondly, with the application of the case study, it became evident that the order of execution of data ingestion and data preparation phases of the PM4CSI framework depends on the offerings provided by choice of process mining tool selected for the improvement initiatives. The order of phases, as shown in Figure 6.1 is accurate for most process mining tools provided by the key players (refer B.2).

Thirdly, even though the framework is based on the application of process mining techniques, one has to follow all the best practices suggested by the ITIL framework to achieve value and success out of the improvement initiative consequently.

Lastly, the steps in the framework could change due to innovation and advancements in the research fields, which could influence the application of cutting-edge technology in service process improvements using ITIL practices. For instance, process mining tools are researching to include AI capabilities to develop the tool for direct usage without requiring a technical data engineer. Hence, to retain the proposed framework valuable and viable, it is best to revise it every few years so that the most recent advancements are covered correspondingly.

8.3 Recommendations for Framework Adopters

The outcome of the current research allows ITSM practitioners to assess and improve any service processes using process mining techniques, given the availability of at least minimal data requirements for process mining and the right expertise stakeholders. Practitioners of continual improvements often carry on the initiative through the traditional approach. The capabilities of process mining constantly evolving and complementing the automation capabilities (ref Gartner's view in Section B) make it a perfect technology to enhance and enable better management of service operations in a fact-based manner. IT and business are increasingly considered integrated fields, allowing businesses to solve problems and make managerial decisions. Bridging the gap between process mining and continual service improvements enables a Business Information Technology practice that allows analysis of specific service process data and helps to plan the service improvements accordingly using the trends and information presented in process-oriented data.

From the perspective of maturity, it is an expectation set that the application of process mining techniques requires a certain level of workflow maturity before applying the PM4CSI framework for continual service improvements. However, this has been taken into account by performing necessary checks during the activities of *Project Initiation* phase. It can be rationalized that it would be challenging to under a process mining service improvement project with poor standardization of service operations, lack of process instance tracking, and lack of process mining software license. Therefore, the framework can be used only when there is an opportunity to improve service process candidates in a data-driven approach.

What is required for an organization (not part of the research) to use the proposed process mining service improvement framework (PM4CSI)?
The framework can be applied in practice by any organization or any ITSM or ITIL practitioner for service process improvements. During the framework validation, experts from both process mining and ITIL domain (strongly) agreed that the framework was understandable, comprehensive, had appropriate steps for both domain and were easy to use. With the knowledge, right expertise onboard, and availability of the correct scope of data, the PM4CSI framework can be introduced for continual improvements of any ITIL/ITIL processes. Therefore, The framework allows the practice of versatile ITSM use cases for various levels of complex service operations and cross-organizational data source systems.

8.4 Recommendations for Consultancy

This research was conducted under the sponsorship of Deloitte, and with the help of the Deloitte People Network, the following recommendations aim to provide business advice for further consultancy opportunities.

The demand for IT services in the industry has been indicated by the increased cloud-based offerings, increased IT spending, and wide adoption of software-as-a-service. Optimal utilization of high-volume process-aware data reserves from the organizational information systems will serve as a barometer that enables teams to recognize which ideas for change are advantageous and require improvement to achieve the desired results. Also, data-driven analysis with the help of technology has been seen as a vital driver for strategic decisions globally.

The organizations and experts interviewed are currently inquisitive about service improvements with compelling technologies such as Process Mining. However, it has been found that organizations need to be equipped with the right tools and methodologies to envision such data-driven approaches. Also, a methodology alone will not be sufficient to carry out a process mining service improvement project. The experts strongly recommend having domain experts alongside to understand the way of working and tie it back to reality. For this reason, the first recommendation for Deloitte is to collaborate with clients with service management capabilities to educate them about the cutting-edge technology - Process Mining which could benefit all parties. The designed framework can also be extrapolated to other shared services provided the availability of data for process mining analysis.

Lastly, integrating process mining techniques into service improvement practices is a new interest in the service industry. Based on experts' opinions, there are benefits to approaching service improvements by leveraging process mining technology to generate value. Deloitte can further explore the value model for such an application to ensure value return on investments.

Chapter 9

Conclusion

Various findings have resulted from this research regarding the use of process mining in continual service improvements. Consequently, the research findings have been addressed based on research questions. Additionally, the research contributions are presented in Section 9.2.

9.1 Main conclusions

The goal of the research is to provide an answer to the following central research question:

What constitutes a framework to assess and improve ITSM processes by leveraging process mining techniques in their ITIL continual improvement practice?

This central question gave structure to the goal of this research to improve ITSM operations by leveraging process mining techniques in the continual improvement initiative. The following sub-questions were addressed in this study to answer the main research question and to guide this research. In the following, the answers to each sub-questions

9.1.1 ITSM Process Improvement Methodologies

In this section, the research sub-question RQ1 is answered:

What are the process improvement methodologies for ITSM processes described in the literature?

ITSM focuses on a set of well-defined and well-established processes that conforms to standards such as ISO/IEC 20000-1 and best practices such as ITIL. To effectively manage IT services, several guiding principles have been provided by standards like the ITIL, ISO/IEC 20000-1 [31], ISO/IEC 15504 [29], COBIT5, CMMI-SVC [32, 6], MOF 4.0 [52], and HPSM Framework [53]. During the framework refinement interviews, Expert E11 (refer Table A.2) mentioned that E11 has been practicing Lean for Continual Improvement. Based on the systematic review by Mesquida [29], the most widely adopted standards for ITSM are the V2 and V3 versions of ITIL, ISO/IEC 20000, and CMMI-SVC. ISO/IEC 20000-1 is an international standard for ITSM [55], which promotes the best practices for planning, implementing, operating, monitoring, reviewing and improving a service management system. CMMI-SVC is a guidance model for improving service quality [32] by applying CMMI best practices.

ITIL is a framework that provides detailed best practices for IT activities, and it facilitates the high-quality delivery of IT services at a reasonable cost. Even though there are different standards and frameworks available to contribute to the ITSM discipline, ITIL is the most commonly used framework for following best practices of ITSM [29]. ITIL is the de facto standard of reference model accepted for ITSM and is adopted globally [4], even though there are different standards and frameworks available to contribute to the ITSM discipline. More than 80% of the studies found in this research's SLR focus on practices provided by ITIL, some of which do not mention any indication of the framework or methodology of their ITSM processes. It is to be noted that ITIL has released its latest version in the year 2019 [2]. While ITIL V3 consisted of 26 processes, the latest version released in 2019 called ITIL V4 consists of 34 practices to manage diverse capabilities that underpin ITSM [54].

9.1.2 Process Mining for ITSM Process Analysis

In this section, the following research sub- question RQ2 is answered:

How can process mining be used for ITSM process analysis?

Process mining techniques have been used for process analysis to identify customer integration in service operations [57], to investigate process performance and social network structure [35], and to identify metrics to reduce the service resolution time [6]. Process mining was also used in studies to detect anomalies and associated risks in service operations [9, 59, 60], to discover if actual operations comply with predefined process model [58], and to analyze user inputs and their correlation with the request resolution time [14]. Various process mining techniques help analyze ping-pong behaviour, first-call resolution, waiting times, process conformity and performance. Different process mining tools were used, such as Disco for mapping processes to understand data flow and manipulation, Celonis to discover processes for time analysis, and Rapid ProM to conduct performance checking. Process mining has been used to analyze the time consumption of process activities, such as waiting time to optimize resource allocation and manage workload or to assess the quality of the service [61]. During the case studies of this research, process mining techniques were used to analyze deviations, performance, and organizational resource utilization in incident management processes.

9.1.3 Process Mining to Improve ITSM Processes

In this section, the following research sub-question RQ3 is answered:

How can process mining be used to improve ITSM processes?

Process mining is generally seen as an enabler of solid fundamentals for future process improvements [35]. Considering the types of process mining as mentioned in section 3.1.5, process mining can be used to analyze, design rapidly, and simulate processes. Thus process mining can be used for the 'plan', 'do', and 'check' stages of the Deming cycle [62] and subsequently, the 'act' stage will be decided and performed by humans either manually or by hybrid intelligence, [58, 63]. Process mining analysis of service processes helps organizations improve the quality of customer service by increasing operational efficiency and customer satisfaction [64]. However, it is crucial to assess the current situation, as, without baseline measurements, it is impossible to make improvements visible [58]. No literature found during this research described how to leverage process mining techniques to improve ITSM processes. The current research was focused on building the gap between process mining and ITIL Continual Improvement Model for ITSM process improvements. PM4CSI V1.0 provides structured guidelines on leveraging process mining techniques in continual service improvements.

9.1.4 Process Mining Approaches in ITSM Sphere

A methodology provides the theoretical framework for best practices in a specific case, from planning to achieving project goals. In this section, various process mining methodologies in the literature are described, and the following research sub-question RQ4 is answered:

What are existing process mining approaches adopted by ITSM practitioners?

A suitable project methodology is a fundamental requirement for the application of process mining to improve business operations successfully. Multiple case studies on process mining can be found in the academic literature, but only a few focus on the process mining project methodology and the managerial implications of its implementation. The approach adopted by [9] to analyze the process-related information in a data-driven process mining project was as follows: Planning, Data preparation, Conformance analysis, Discovery analysis, and performance analysis. Process mining on incident management process data to analyze the relationship and change of statuses of events to improve or redesign processes used a cascade methodology with the following steps: (1) data extraction from the current process, (2) Data filtering and normalization, (3) Process Mining Analysis (4) analysis of results, and (5) improvement of the process based on observed results [65]. Inspired by the Aalst's L* lifecycle model [11], a case study for a question-driven process mining project [6] followed a few steps as shown in Figure C.6 for successfully analyzing incident management process and defining metrics for improvement in a global Brazilian organization. Process mining of data associated with the IT service tickets consists of data extraction and preprocessing of data to generate event logs. It has been found that the existing literature did not follow or adopt any standardized process mining approach, even the popular and proven methodologies like PM^2 methodology [67].

9.1.5 Prerequisites for Process Mining Application

In this section, the following research sub-question RQ5 is answered:

What are the prerequisites for applying process mining to ITSM process improvements?

Three aspects referred to as the "three Ps" of Process Mining are crucial for the successful application of process mining in any improvement project, namely *Purpose* - specific project purpose or demand to deliver value, *People* - to ensure operational excellence by building insights and turning them into actions, and *Process Traces* - identification, collection, and customization of digital process-related data [33]. It is essential to understand the concept of Garbage In and Garbage Out as low-quality and unrepresentative data input for a process mining use case provides little or no value to organizations and often leads to erroneous conclusions [76]. Following pre-conditions were considered while performing process mining on service processes [57, 35, 9, 6, 14]:

- Service processes should be implemented in a PAIS such that the execution of every activity should be recorded.
- Event logs can then be gathered from any business processes, either standardized or customized.
- Service processes that are to be analyzed should at least contain more than one activity.
- Every process instance should belong to a particular process, and every event should refer to a particular case.
- To mine resource perspective, the activity should be assigned to more than one resource executing it.
- It is necessary to check if the extracted data is compatible with the selected process mining

tool. Thus an event log should be generated before applying process mining techniques.
- It is important to formulate KPIs, as, without them, it is impossible to check conformance.
- To perform a conformance checking, the desired business process should be available as an apriori process model so that discrepancies between modelled behavior and observed behavior can be identified and investigated.

Most of the literature found during the SLR stated that XES is the event log format for mining a process using process mining tools such as Disco and ProM. However, tools available in the market, such as Celonis, have evolved to avoid such format implications as long as the event data is SQL readable. The expert interviews and case studies of this research confirmed that data ingestion happens by live data connection using data connectors corresponding to different information systems. In the case of data extractions, the file format can be any format, such as XES, CSV, XLS, and JSON.

9.1.6 ITSM process candidates for applicability of process mining

In this section, the following research sub-question RQ6 is answered:

Which ITSM processes are suitable for improvements using process mining?

The underlying relationship between variables was identified using process mining and simulation combined, and visual models can be developed. Two ITSM processes, namely Change Management and Incident Management, were covered during the case study to design a predictive model to support lessening the workload impact of Incident Management operations [66]. Process mining has been used to discover anomalies in the process by exploring an incident management event log [59]. In practice, process mining has value in change management, incident management, problem management, request management, and vulnerability management, where the process traces are available, and activities are repeated. For more description of these ITSM practices, refer to Table A.1.

9.1.7 Framework Development

In this section, the following research sub-question RQ7 is answered:

How can a framework be developed for the application of process mining techniques to improve ITSM processes?

The answer to this question has been determined based on the information collected for the previous sub-questions and the insights gathered during two series of framework refinement interviews.

Firstly a process mining approach was developed with the context of improving service processes based on the information collected during the literature review. Since this question aims to develop the application of process mining to improve service processes, ITIL has been chosen as a standardized ITSM improvement framework. The rationale behind choosing ITIL is because it is a de facto standard of reference model accepted for ITSM and is adopted globally [4]. To leverage process mining techniques and capabilities in the process improvement practice provided by ITIL, the developed process mining approach has to be mapped to the seven steps of ITIL Continual Improvement Model to ensure that the process mining approach adapts to the Continual Service Improvement practice. Consequently, the initial version of PM4CSI framework has been created as PM4CSI V0.1.

Considering only a few of the limited resources obtained through SLR were empirically validated, to ensure validity, generalizability, and relevance, and to close the gap between literature and practice with the advancements in the research fields, experts were interviewed meticulously following empirical guidelines and protocol to collect qualitative factual information regarding the end-to-end process mining approach in continual service improvement context. Such interviews contributed by adding value to areas that needed to be clearer through a literature review. It also ensured mitigating the researcher's bias in developing the refined version of the framework, PM4CSI V1.0.

Thus the PM4CSI V0.1 framework was ex-ante validated through two series of expert interviews with domain experts from both process mining and ITSM practitioners, and based on their feedback, the PM4CSI was adapted to build the refined version of the framework, PM4CSI V1.0. The developed, refined version PM4CSI V1.0 results as a framework to assess and improve ITSM process using process mining techniques by presenting the results into tabular and explanatory textual information.

9.1.8 PM4CSI Framework Validation

In this section, the following research sub-question RQ8 is answered:

How effective is the developed framework in practice?

Two validation episodes were conducted to answer the research question above.

The first validation method consists of expert interviews with process mining center of excellence consultants from different organizations and ITIL certified experts. This set of stakeholders represents the intended users of the PM4CSI V1.0 framework and has experience with continual process improvements at multiple organizations. The process mining and continual improvement experts visualize the use of the PM4CSI V1.0 in a real-world setting and then express their judgment on the evaluation criteria based on it. Consequently, such interviews result in an *artificial* evaluation paradigm. Multiple interviews with different consultants were performed to improve the validity and generalizability of the findings. To critically evaluate the relevance, practicality, usability and utility of the PM4CSI V1.0 framework, survey questions were designed based on the constructs of the Technology Acceptance Model (TAM) [92]: Perceived usefulness, perceived ease of use, and attitude towards using, which evolved as an intention to use in TAM2 [21].

The second episode of validation was through case studies. The purpose of this evaluation is more summative, as it aims to conclude the research. It explores the efficiency of the PM4CSI V1.0 framework by assessing real-world processes and participants. Multiple case studies were performed to improve the validity and generalizability of the findings, along with evaluating the practicality and tool independence nature of the PM4CSI V1.0 framework. Two case studies with three different process mining market tools were conducted by applying the PM4CSI V1.0 and observing the effects.

Thus the refined version, PM4CSI V1.0, was first validated through ex-post expert evaluation interviews and a survey with seven experts in the field of process mining, ITSM, and continual improvement. While the ex-ante interviews during framework refinement prove the validity of the PM4CSI V1.0 framework, these ex-post evaluation interviews confirm the potential and utility of the PM4CSI V1.0 to be adopted in practice and for application in the real-world problem context. Secondly, it was validated through the case studies, confirming and satisfying the utility, usability and tool-independent applicability of the PM4CSI V1.0.

9.1.9 Concluding Remarks

ITIL provides a Continual Improvement Model with seven steps as a high-level guide to support improvement initiatives in an organization [2]. Utilizing the model makes ITSM activities more likely to be successful, places a strong emphasis on customer value, and ensures that improvement initiatives can be traced back to the organization's goal. In the past decade, process mining has emerged as a superior technology to assess and improve ITSM processes in a more efficient way [35, 9, 14, 58, 6, 97]. Hence, process mining is one of the enabling technologies for process improvement frameworks such as ITIL.

Only one research showed how Process Mining could check compliance of as-is processes with to-be processes through a Continuous Process Improvement reference model, followed by the ITIL V3/2011 seven-step Continual Service Improvement procedure [12]. Nevertheless, the need for a structured method guiding when and how to leverage process mining techniques to perform ITIL Continual Improvement activities effectively has formed the objective of this research. Consequently, based on the research objectives, a framework called Process Mining for Continual Service Improvements (PM4CSI) has been developed. The difference between the initial version of the PM4CSI framework created by reviewing the scientific literature and the refined version by gathering information from industry experts shows the gap between academy and practice. It can be argued that the faster pace of advancements in the field of process mining creates such gaps between existing scientific documentation and organizational practice. PM4CSI supports organizations and ITSM practitioners to assess and improve their ITSM operations by complementing their ITIL Continual Improvement initiative. Thus, with PM4CSI framework, ITSM practitioners, or any organizations aiming to improve the ITSM processes have a standardized operating framework guiding to leverage process mining techniques for continual service improvements.

PM4CSI framework has three parts: a high-level graphical abstract, a detailed graphical overview of the framework and a detailed explanation of PM4CSI phases. The detailed explanation covers level-wise explanatory text in the form of an activity flow diagram and tables. Additionally, a table depicting the resources required, responsible roles, the input, the activities and the output of each phase of PM4CSI. PM4CSI has not been developed with the aim of replacing ITIL Continual Improvement Model. Rather, the PM4CSI framework should be seen as an approach to complement continual service improvements using process mining techniques. PM4CSI is a process-independent, tool-independent, comprehensive, domain-relevant framework that accounts for business knowledge and supports iterations through the improvement initiative. For these reasons, ITSM continual improvement and process mining experts find the PM4CSI framework as highly useful guidelines to assess and improve ITSM operations. Thus, PM4CSI satisfies the objective of this research.

9.2 Contributions

9.2.1 Contribution to Science

Existing research on ITSM process improvements using process mining techniques does not provide ITSM practitioner with a standardized guideline on conducting a process mining service improvement project. This research bridges the gap between Process Mining and ITSM by designing a framework that allows ITSM practitioners to effectively perform ITIL continual service improvement practice using process mining techniques. Additionally, PM4CSI serves as a generic process mining methodology for organizations requiring a detailed approach to improving processes by leveraging process mining techniques. Thus, this research adds value to both ITSM and Process Mining fields by integrating the process mining approach into ITIL Continual Improvement Model.

The PM4CSI V1.0 framework was designed by leveraging existing peer-reviewed guidelines, methodologies, and approaches, such as Design Science Research Methodology [13], Systematic Literature Review [51, 19], Qualitative Data Collection [81, 80], Framework for Evaluation in Design Science [22], and Straussian Grounded Theory for Data Analysis [85]. Additionally, the current research is built on top of existing approaches and practices. PM4CSI is a complementary guideline developed by comparing existing approaches rather than creating a new guideline. Thus, the research also contributes to the research coherence by demonstrating an approach that enables adding value to existing knowledge.

9.2.2 Contribution to Practice

The practical contribution of this research is twofold. Firstly, this research introduces a process mining framework for service improvement practice to assess and improve the service processes using process mining techniques. Second, this research is an evaluation with field practitioners, ITIL and process mining experts, and organizations, indicating that the proposed framework is a promising guideline for practice.

ITSM practitioners can directly use the PM4CSI framework as it was designed based on the recommendations of ITIL Continual Improvement Model. Besides guidelines, this thesis also provides a detailed approach to what prerequisites, roles, and outputs should be considered to achieve value milestones in an improvement project. ITSM practitioners generally perform Continual Service Improvement initiatives and PM4CSI complement these assessments.

Process mining provides transparency through its capabilities, which enormously support ITIL Continual Improvement process and support the experts to perform improvements with more focus, less effort, and better results. The process mining, ITSM and continual improvement experts, who are the intended users of the PM4CSI framework, assigned positive scores to the research's evaluation criteria. Such evaluation indicates that PM4CSI is a useful, easy-to-use, and practical framework for real-world service improvement project implementation.

9.3 Limitations

This section addresses the limitations subject of this research.

Firstly, the study originates from a qualitative methodology. The collected studies for literature review were critically analyzed with an ad-hoc strategy inspired by [51]'s checklist. Nevertheless, the data collection, extraction and synthesis conducted for the literature review section of this report were plausible and subjective because they resulted from the work of only one researcher (author). However, the validity of the literature review was enhanced by adopting empirical guidelines.

Secondly, the framework refinement process involved expert interviews, which could lead to biases both from the researcher and interviewee ends. Consequently, the results could be biased and driven towards the individual's perspective. However, designed interview protocols were peer-reviewed to eliminate such bias, and a pilot interview was conducted with experts. The coding process for the interview results was also peer-review to eliminate the researcher's bias. The validation interview through the experts' opinions followed a protocol where the survey statements were negated to avoid monotonous responses and eliminate potential bias. Validation case studies were also conducted in this research.

Another limitation of this research is potentially caused by the population sample chosen for both rounds of refinement interview, validation interview and case studies. Although data saturation was achieved through two rounds of 19 different interviews with at least 12 experts as recommended [80], the findings from these processes could be subject to certain limitations, such as achieving expected levels of data saturation. Nevertheless, the involved participants were meticulously chosen based on demographic diversity to mitigate potential data saturation risks.

Besides the conducted interviews, an rigorous validation approach has proven great potential for credibility enhancements of the research outcomes. Case studies even proved the satisfaction of various requirements as stated in section 2.2. However, Case 1 was conducted with mock participants, and open data and Case 2 acted as a single-case design validation. Also, due to resource constraints in the first case study and time constraints in the second case study, at the time of writing this report, all the phases of the PM4CSI have not been validated. Thus, the validation quality might have improved with an increased number of cases. However, considering the research process, i.e. designing a framework based on scientific literature resources, refining the framework through field experts, and validating the framework with another set of field experts and potential users of the framework, the generalizability and validity have been taken care of during this research.

Another limitation of this research's output is that the framework's detailed overview has been designed using Bizagi Modeller. Non-technical persons might find the artifact challenging to understand at the first glimpse of the PM4CSI framework. However, comprehensive guidelines were provided in textual and table formats for precise documentation.

9.4 Directions for Future Work

The continual improvement process at Company ABC as a part of Case Study 2 will continue even after writing this report. During this research, the researcher identified a client use case with another organization, say XYZ, a Dutch landline and telecommunications company. Thus, the researcher has planned on continuing to work with ABC and XYZ further to refine the PM4CSI V1.0 and provide further discussion on its execution and results. Besides these two, several new opportunities have been identified through this research for future research.

The nature of this research is qualitative, and in combination with time and resource constraints, have led to certain limitations related to the validation of this research. Future work can include further evaluation of the research artifact and outcomes. One way of performing such research is by extending the single case study validation to follow multiple technical action research evaluation methodology [13]. Another approach could involve a quantitative approach by increasing the evaluation participants.

The PM4CSI framework acts as a guideline for ITSM practitioners to effectively assess and improve the service process using process mining techniques. A ready-to-use solution can be developed using the process mining market tools to develop connectors and customized dashboards with a predefined set of performance indicators. Using such a solution, the business leaders can directly utilize the effectiveness of the tool support built on the PM4CSI guideline for continually assessing and improving their service processes, thereby ensuring operational excellence. Thus, future work could focus on developing tool support to complement the PM4CSI guideline enabling more effectiveness for non-technical users to benefit from the framework with limited technical employment.

The literature review led to finding research gaps in the research fields. This research focused on fulfilling one of the research gaps identified during the literature review. One of the other research gaps includes analyzing the effort required for successful process improvements using process mining techniques. During the framework refinement interviews, questions were posed to the field experts regarding the time taken for each of the phases in a process mining improvement project. Four out of thirteen experts interviewed were only able to provide an answer to such questions. However, even considering only those four data sources, saturation still needed to be achieved. Only two experts provided similar answers as described in Section 5.2. The answer provided by those two experts was conditional based on the availability of three P's as shown in Figure 3.13 [33]. Time management is one of the most crucial knowledge areas in any project because it directly affects a project's quality, scope, and cost. Time management ensures project completion on schedule and within budget. One way to estimate the time and effort required for process mining improvement projects could focus on collecting relevant project management data by increasing the sample population and performing a quantitative analysis by analyzing the data and surveying key stakeholders.

During case study participant selection, it was found that only ITSM incident management event data were available as open access data. Even during the involvement with various client organizations, the suggested process area was focused on incident management due to time constraints and easier extraction of relevant data. Thus, the other research gap identified during this research was to focus on research that builds a value model for applying process mining techniques for different ITSM operations. Such research will enable practitioners to invest in the right solution for valuable process outcomes.

Therefore, the research identifies various new opportunities for future research work, which indicates the value of extending research on this topic and developing new theories.

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Appendix A

Introduction

A.1 ITIL Service Management Practices

Availability Management	Ensuring services deliver the agreed availability levels to meet the requirements of customers and end users.
Business Analysis	Analyzing the business and related elements, to define business needs and provide recommended solutions to address the business needs and/or solve a problem. This practice enables value creation for stakeholders' objectives
Capacity and Performance Management	Ensuring services achieve expected and agreed performance to satisfy current and future demand while being cost-effective.
Change Control	Maximizing the rate of successful service and product changes by properly assessing risks associated with it, authorization of changes for approval, and maintaining the change schedule. Note: Change is the addition, modification and removal of anything that could have direct or indirect effect on services.

Table A.1: ITIL Service Management Practices [2]

Incident Management	Minimizing the negative impact of incidents by restoring regular and normal service operation as quick as possible. Note: Incident is an unplanned interruption to a service or reduction in the quality of a service.
IT Asset Management	Planning and managing the entire lifecycle IT assets. This helps an organization to maximize value, manage risks, control costs, support decision making right from procurement to disposal, and meet constantly evolving regulatory and contractual requirements. Note: IT asset is any commercially valuable component that can contribute to the delivery of an IT service or product.
Monitoring and Event Management	Periodic observation of services and service components to record and report selected changes of state identified as events. Note: An event is any change of state that has significance for the service or other configuration management.
Problem Management	Reducing the likelihood and impact of incidents by identifying real and potential causes of incidents, managing workarounds and known errors. Note: A problem is a (potential) cause of one or more incidents and a known error is a problem that has been analyzed but not resolved. A workaround is a solution that eliminates or reduces the impact of a problem or incident for which full resolution is not yet available.
Release Management	Making new or modified services and features available for use by service consumers
Service Catalogue Management	Provision of single source of consistent information on all services and offerings and ensure its availability to all relevant audience.
Service Configuration Management	Ensuring accurate and reliable information on the configuration of services and configuration items that support them is available.
Service Continuity Management	Ensuring the maintenance of availability and performance of service at sufficient levels in case of disasters.
Service Design	Designing products and services that are fir for purpose, use, and can be delivered by the organization. This includes planning and organizing people, suppliers and partners, information, technology, communication and practices.

A.2 Domain Experts Consultation

During the interviews conducted throughout this research, the several participants consulted had expertise in the field of process mining, and/or ITSM, and/or continual service improvements. Table A.2 provides a list of domain experts involved in this research, their current role, company, geographical location, gender, and contributions to this research. Nevertheless, the process mining experts interviewed clearly understand and have been engaged in the end-to-end activities in an improvement project.

Organization Overview

To ensure this research's generalizability and global applicability, interviews were conducted with experts from different organizations. The following list briefly describes the organizations where the experts are currently working.

- **Company A** - Netherlands-based Services and Consulting Firm specialized in process mining.
- **Company B** - Netherlands-based Strategic Consulting startup specialized in process mining and business process management.
- **Company C** - The majority of the interviewees originated from Deloitte, a leading global service provider of consulting, financial advisory, audit and assurance, risk advisory, tax, and related services. The experts were active in process mining and/or service management. The experts have been active in projects in different client scenarios, improving the interview results' generalizability.
- **Company D** - Global consulting firm that provides clients with consulting and managed solutions in finance, technology, operations, data, analytics, governance, risk, and internal audit.
- **Company E** - An American multinational technology corporation producing computer software, consumer electronics, personal computers, and related services. The company is headquartered in Washington, United States.
- **Company F** - A Dutch landline and mobile telecommunications company making technology accessible for many years.
- **Company H** - Leading global distributor of off-grid energy such as LPG and LNG and is active in the area of sustainable fuels and renewable energy solutions
- **Company I** - An American multinational information technology services and consulting company headquartered at New Jersey, United States.
- **Company J** - A multinational professional services partnership headquartered in London, England. Company J has one of the largest professional services networks in the world and is considered one of the Big Four accounting firms.
- **Company K** - German multinational pharmaceutical and biotechnology company with a more than 150-year history and core competencies in the areas of health care and agriculture. The company is headquartered in Leverkusen, Germany.
- **Company L** - A company active in organizational consultancy branch at Tilburg, The Netherlands.
- **Company M** - An Indian multinational corporation that provides information technology, consulting and business process services.

Expert	Position	Industry Experience	Current Company	Geographical Location	Gender	Source of connection	Contribution
E01	Process Mining Manager	5	Company A	The Netherlands	Female	LinkedIn Network	-First round of framework refinement interview
E02	Senior Process Mining Consultant	10	Company B	The Netherlands	Male	LinkedIn Network	-First and second round of framework refinement interview
E03	Senior Process Mining Consultant	3	Company C	Germany	Male	Deloitte People Network	-First and second round of framework refinement interview
E04	Global Business Process Transformation Leader	25	Company D	The Netherlands	Male	Deloitte People Network	-First round of framework refinement interview
E05	Senior Process Mining Consultant	5	Company C	Germany	Male	Deloitte People Network	-Insights on process mining use-cases to narrow down the research focus area -First and second round of framework refinement interview
E06	Process Mining Manager	8	Company C	New York, United States	Female	LinkedIn Network-*Women In Process Mining*	-First and second round of framework refinement interview.
E07	Senior Product Lead	10	Company C	The Netherlands	Male	Deloitte People Network	-Introduction to Process X-ray tool. -Insights on process mining use-cases to narrow down the research focus area -First round of framework refinement interview
E08	Process Mining Excellence Center Consultant	3	Company C	Germany	Male	Deloitte People Network	-Insights on process mining use-cases to narrow down the research focus area -First and second round of framework refinement interview
E09	Data Analytics Associate Director	16	Company D	The Netherlands	Male	LinkedIn Network	-First and second round of framework refinement interview
E10	Senior Process Mining Software Development Engineer	6	Company E	Washington, United States	Male	LinkedIn Network	-Second round of framework refinement interview -Validation of the framework through the Expert Opinion method.

Table A.2: List of domain experts interviewed and their contributions to this research

Expert	Position	Industry Experience	Current Company	Geographical Location	Gender	Source of connection	Contribution
E11	Director Continual Service Improvement	13	Company F	The Netherlands	Male	LinkedIn Network	-Insights in Challenges on ITSM -Second round of framework refinement interview
E12	Digital Transformation Technologist	15	Company G	Belgium	Male	LinkedIn Network	-Second round of framework refinement interview
E13	Process Mining Center of Excellence Manager	10	Company C	India	Male	LinkedIn Network	-Second round of framework refinement interview
E14	IT Service Manager	20	Company H	The Netherlands	Male	Deloitte People Network	-Insights on Challenges in ITSM
E15	Service Delivery Manager	16	Company I	India	Female	Author's Previous Employer Network	-Insights on Challenges in ITSM
E16	IT Service Management Senior Manager	13	Company C	The Netherlands	Male	Deloitte People Network	-Insights on Challenges in ITSM
E17	ServiceNow Practice Head	13	Company J	The Netherlands	Male	LinkedIn Network	-Insights on Challenges in ITSM
E18	Operations Transformation Manager	7	Company C	Canada	Male	Snowballed through E06	-Validation of the framework through the Expert Opinion method.
E19	Process Mining Center of Excellence Lead	19	Company K	Germany	Male	Snowballed through E06	-Validation of the framework through the Expert Opinion method.
E20	Senior Manager	13	Company C	The Netherlands	Male	Deloitte People Network	-Validation of the framework through the Expert Opinion method.
E21	Manager	9	Company C	The Netherlands	Male	Deloitte People Network	-Validation of the framework through the Expert Opinion method.
E22	Senior ServiceNow Consultant	22	Company L	The Netherlands	Male	LinkedIn Network	-Validation of the framework through the Expert Opinion method.
E23	Technical Lead	10	Company M	India	Male	LinkedIn Network	-Validation of the framework through the Expert Opinion method.

Table A.2: List of domain experts interviewed and their contributions to this research (*Continued*)

Appendix B

Market Research on Process Mining

Following sources published by top technological research firms and magazines were consulted to gain knowledge on the current trends, practices, and adoption of process mining by organizations worldwide.

- Gartner
- Forbes
- Harvard Business Review
- Fortune Business Insights
- International Data Corporation (IDC)
- EMIS

B.1 Process Mining Capabilities

Forbes mentioned process mining as a solution that enables automated, real-time optimization process which can fix everything from the supply chain to the planet. The Harvard Business Review has advised businesses to explore and start using process mining. Companies with over $2 billion of revenue have been known to save over $10 million by acting upon the insights their process mining software illuminates for them. In the following, the capabilities of process mining identified by Gartner and the comparison of it with its alternatives has been shown.

1. **Models of processes, exceptions and process instances (mostly referred to as "cases"), and employee interactions** — Automated discovery of process models, exceptions and process instances, together with basic frequencies and statistics
2. **Support for customer interactions, customer journey maps, and related analysis** — Automated discovery and analysis of customer interactions, as well as alignment with internal processes
3. **Conformance-checking and gap analysis capabilities** — Capabilities to check conformance not only graphically through overlays, but also through data analysis and performing gap analysis
4. **Intelligent support for process model enhancement** — Enhancing or extending existing or a priori process models by using additional data from the recorded logs and events
5. **Data preparation and data cleansing support, supporting big data** — Different ways to handle data
6. **Real-time dashboards with support for key performance indicators (KPIs) that are continuously monitored and enable decision support** — Real-time or near-real-time

connections to continuously monitored and adapted KPIs in dashboards for specific roles in the organization

7. **Predictive analysis, prescriptive analysis, scenario testing, and simulation** — Advanced analysis capabilities that use contextual data
8. **A platform that extends the process mining capabilities across different processes with advanced analytic capabilities and decision management capabilities and that also offers APIs to create process mining apps** — Allowing organizations and partners of the process mining vendors to create applications, such as financial auditing tools
9. **Task mining** — Inferring useful information from low-level event data available in UI logs. These UI logs describe the single steps within a task done by a user — for example when using a workstation — based on keystrokes, mouse clicks, and data entries.
10. **Execution capabilities that turn "insights" into "action"** — These capabilities could range from simply updating source applications (applications that delivered the events for process mining) to creating scripts that support the execution of tasks.

B.2 End-users Analysis by Fortune Business Insights

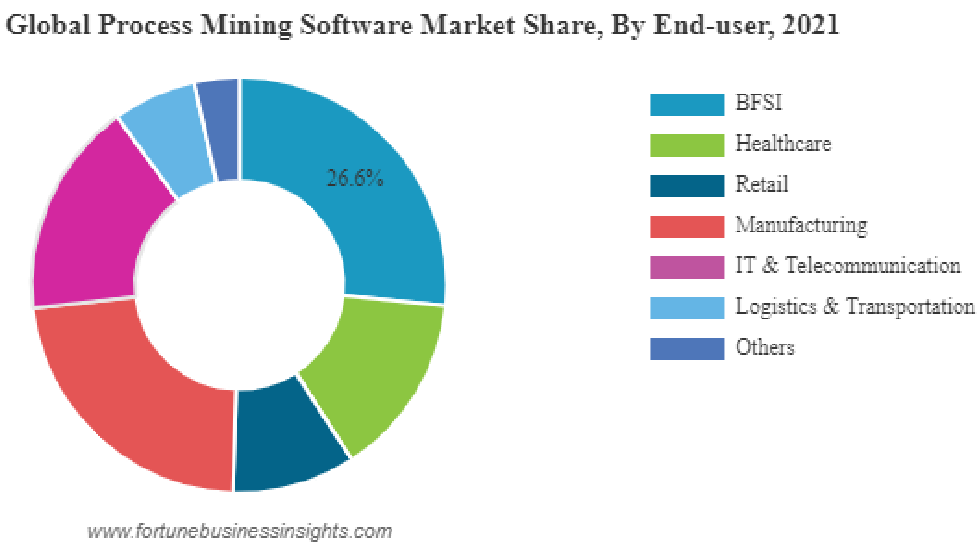

Figure B.1: Adoption of process mining by end-users of diverse industries

According to Fortune Business Insights, the global "Process Mining Software Industry Size" was valued at USD 627.0 million approximately in 2021. From 2022 to 2029, the market has been expected to increase at a robust rate of over 49.5%, and the estimated revenue forecast is USD 15,546.4 Million. It is predicted that Europe to dominate the global market share due to the surge in the implementation of artificial intelligence and rapid digital transformations during the forecast period. Figure B.1 from Appendix B.2 shows the adoption of process mining by end-users of different industries. Also, the key players in the market identified are Celonis GmbH, Fluxicon BV, QPR Software Plc., Software AG, ABBYY Solutions Ltd., Cognitive Technology Ltd., UiPath, Kofax, Minit, Fujitsu Ltd., Exeura, Hyland Software Inc., and Lana Labs GmbH.

Gartner sees task automation, hyper-automation, and operational resilience as drivers for the adoption of process mining in addition to digital transformation and artificial intelligence. The forecast analysis of global process mining adoption by Gartner, based on process mining maturity and technology innovation, showed that process mining had been expected to grow up to $2.3 billion by 2025, with a double-digit CAGR of 33%. By 2024, Gartner forecasts at least 5%-10% adoption of process mining capabilities in the business functions of advanced enterprises driven by goals to reduce cost and achieve automation-driven enhanced process efficiency.

IDC FutureScape Report predicts that by 2023, 35% of businesses will use process mining as a controlling layer for end-to-end business processes, and these businesses will be at least 20% more profitable than their counterparts who do not. Vice president of European AI, Automation, and Analytics quotes the vast potential of process mining to drive business (Source: IDC).

B.3 Analysis of process mining types and use cases

The latest report of Gartner's Market Guide on Process Mining documented the identification of ten process mining capabilities (see Appendix Section B.1). It is foreseen that process mining will expand to various business functions, including IT operations management due to the applicability of process mining techniques in the IT processes, client journey, IoT, and composable business. Their market analysis shows a significant trend that can be seen towards an improved focus on process mining enhancement, whereas conformance seems to stabilize (see Figure B.3 in Appendix Section B.3). Also, figure B.2 shows the predominant application of process mining use cases by Gartner.

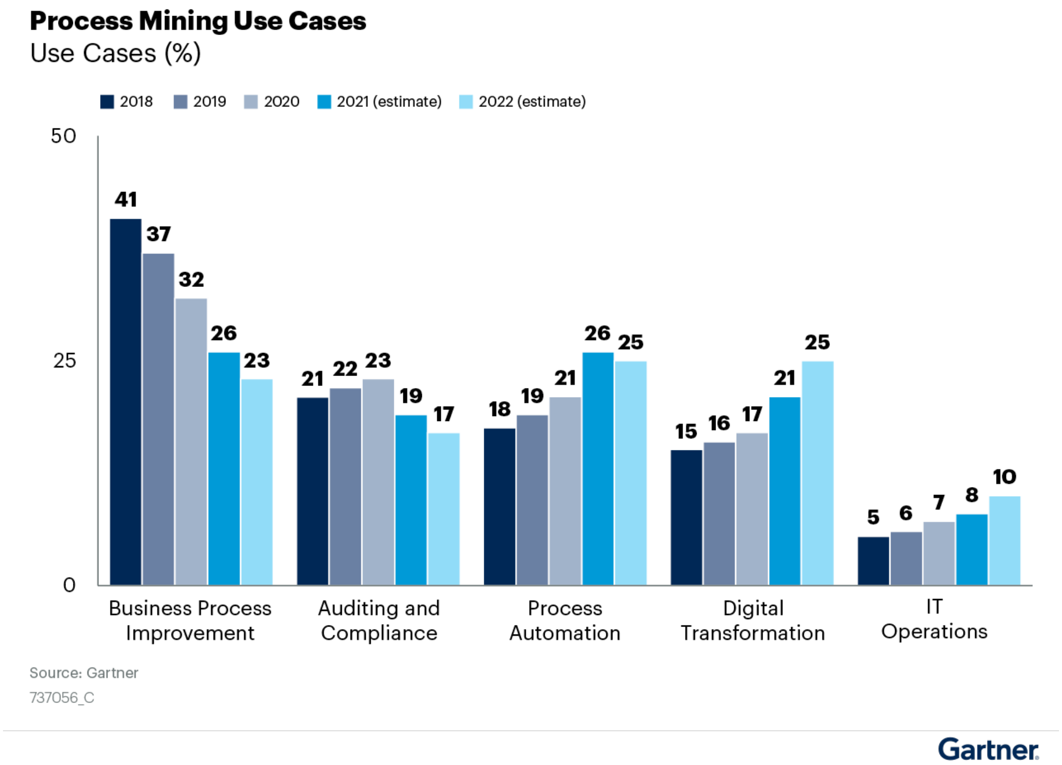

Figure B.2: Gartner's Analysis on the use cases of process mining

EMIS intelligence announced that acquisition of Minit, a process mining solution vendor, by Microsoft validates the process mining value in the enterprise. Process mining and business process intelligence capabilities will soon be natively built into all significant enterprise IT platforms, as evidenced by Microsoft's acquisition of Minit. Another publication by EMIS announced the union of a Brazilian Process Mining specialized startup, Everflow by Pegasystems to evolve the process mining area beyond static modelling and to improve customer operations

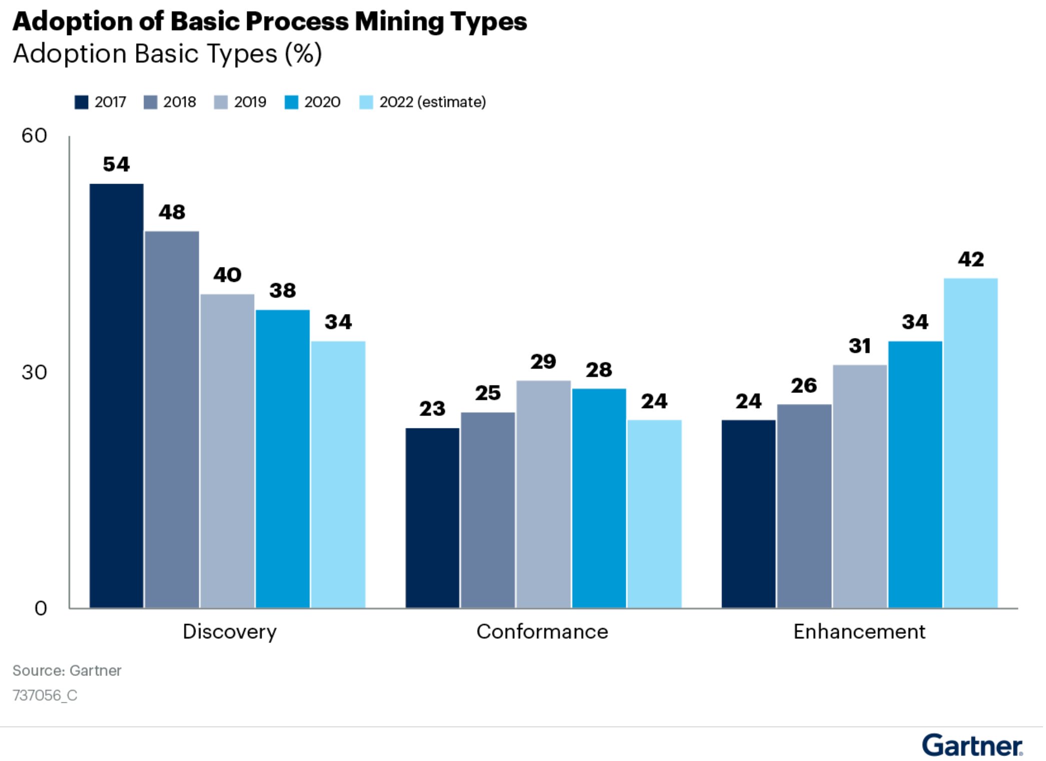

Figure B.3: Gartner Analysis on the adoption of main types of process mining

and experiences by real-time process optimization and corporate-scale hyper-automation. EMIS also published the acquisition of Lana Labs Process Mining Platform by Appian (NASDAQ: APPN). Through a collaborative partnership with process mining software provider Celonis, Accenture hopes to enhance the precision and speed of identifying process bottlenecks (Source: EMIS 29-01-2022). With the acquisition of myInvenio and a strategic alliance with Celonis, IBM enters the process mining market (Source: IDC). Signavio was acquired by SAP, and the business unit for business process intelligence was launched (Source: IDC). These acquisitions show a natural synergy between process mining, modelling, and automation.

B.4 Process Mining Vs Alternatives - Comparison by Gartner

Business processes are interconnected, automated, and complex; hence, assessing and monitoring day-to-day life is challenging. Analyzing the famous research tools in this section, it is evident that process mining fits as a glove to simplify and streamline each analysis point in the process. Figure B.4 in Section B.4 shows Gartner's comparative analysis of process mining with traditional alternatives based on the performance.

Alternatives	Performance Against Objectives			Assessment
	Process Efficiency	Processing Speed and Accuracy	Process Assessment Cost	
Process Mapping: Involves showing graphically the inputs, actions and outputs of a process	**Low improvement:** Traditionally, process mapping tools only provide visibility into the high-level steps of a standard process and not into exceptions.	**Low improvement:** Process mapping is not only time-consuming but also of little analytical value, as it relies on static and partial information to build a process model.	**High cost:** Business managers must develop a document containing information of the detailed activities of the specific process. Continued iteration is difficult and costly.	**Partially meets objective**
Business Intelligence (BI) Software: Involves using software designed to retrieve, analyse, transform and report data for business intelligence	**Low improvement:** BI can highlight process inefficiencies but cannot necessarily isolate their root causes.	**Low improvement:** BI can highlight process inefficiencies but cannot necessarily isolate their root causes.	**High cost:** Extensive analysis is required to isolate root cause problems and identify improvement opportunities.	**Partially meets objective**
Manual Process Mining: Involves performing manually the steps related to process mining	**Medium improvement:** Relies on manual process mapping and recording of timestamps and thereby manual analysis and visualization. Realistically limited in identifying all of the exceptions to the standard process.	**Medium improvement:** Relies on manual process mapping and recording of timestamps and thereby manual analysis and visualization. Realistically limited in identifying all of the exceptions to the standard process.	**High cost:** Relies on manual process mapping and recording of timestamps and thereby manual analysis and visualization. Continued iteration is difficult and costly.	**Partially meets objective**
Process Mining	**High improvement:** Process mining helps identify the **root causes of process inefficiencies.**	**High improvement:** Using data logs, process mining **provides an assessment of real speed and error rates.**	**Medium cost:** Process mining **eliminates the need for interviews** and extracts information from existing IT systems.	**Fully meets objectives**

Figure B.4: Gartner Analysis on the adoption of main types of process mining

Appendix C

Literature Review

C.1 Systematic Literature Review

This section presents an overview of the literature review procedure. Detailed information on the structure of SLR. Section C.1.1 presents the search strategy including the search strings, search query, choice of scientific databases, and inclusion and exclusion criteria. Section C.2 Critical Appraisal of collected studies including the explanation of quality assessment scoring criteria. Finally, Section C.3 describes the data extraction process and synthesis strategy.

C.1.1 Search strategy

To acquire scientific knowledge of the state-of-the-art on the application of process mining in ITSM-specific processes, a review process was designed, which was inspired by Kitchenham [51]. The research questions of this thesis formed the basis for the adopted search strategy.

Search strings

This SLR is conducted using a keyword search approach. The search terms are developed based on the keywords derived from the research questions mentioned in subsection 1.5. To obtain all relevant works available, there is a need to have a semantic criteria search. Hence, relevant words from the thesaurus were included in the search query to have a semantic structure for searching specific papers. To define specifically relevant papers, the "AND" operator is used to ensure that in the searches, there is a connection between process mining and ITSM. The "OR" operator is also used to increase the variety of search results. Although the information related to mentioned keywords can be widely found, only scientifically reliable sources were considered to ensure research quality. A pilot search was performed in Scopus, with the same query as C.1.1) including a focus on the frameworks as follows:

Pilot Search Query *("process mining" OR "workflow mining" OR "process analysis") AND ("IT service" OR "service management" OR "service operation" OR "IT operation" OR "ITSM" OR "ITIL") AND (“framework” OR “methodology” OR “approach”)*

However, it narrowed down the results to limited literature works. To ensure that existing academic literature on the topic of the research's interest are not left out, C.1.1 was finally used to retrieve documents from the chosen electronic databases.

Literature identification

The development of the search strategy is based on the adoption of the following methods from [51]:

- Present the review protocol to the supervisors for review and criticism.
- The search strings are appropriately derived from the research questions.
- Piloting the research protocol to find mistakes in data collection, if any.

Scientific Databases and Search Query

The databases mentioned in Table 3.1 are selected to cover publications relevant to our interest. These databases covered a substantial number of publishers. To eliminate a high amount of duplicate papers adding more sources is less likely to result in additional relevant papers. Exploring the Google Scholar database did not result in the most relevant novel papers, which confirmed this assumption. The search is facilitated by the Utwente Library Network, making it possible to access all the publications open to the university.

For searching the relevant documents, the databases by setting the search within as shown in Table 3.1 are searched with the query structure as follows:
("process mining" OR "workflow mining" OR "process analysis") AND ("IT service" OR "service management" OR "service operation" OR "IT operation" OR "ITSM" OR "ITIL")
This resulted in 149 research documents. The search was narrowed down to publications listed from 2009 till the present since the IEEE Task Force on Process Mining was established in 2009 to promote the research, education, development, and understanding of process mining [39]. This action resulted in 125 documents. Furthermore, the search was scoped down to only document types as mentioned in Table 3.1 from the corresponding e-databases. Consequently, 106 literature studies have been obtained. The Zotero bibliography management tool eliminates the duplicate documents from these 106 documents. Consequently, 83 unique literature documents were acquired for this research. Visualizing the count of literature published over the years (refer to graphical figure C.1), it can be assumed that since the Covid pandemic, there has been a drop in conference and journal articles corresponding to the use of process mining in the service industry.

C.1.2 Inclusion and exclusion criteria

Initially, the studies were selected by running the search query with filters mentioned in subsection C.1.1. The following inclusion and exclusion criteria have been used to identify the studies that support our interests.

- Inclusion criteria:
  - IC1 The paper relates to this research interest, i.e., papers directly address the information on the interest of the research questions mentioned in subsection 1.5.
  - IC2 The paper has open access and is available for download.
  - IC3 The paper is in English.
  - IC4 The paper is from a peer-reviewed journal or conference.
- Exclusion criteria:
  - EC1 The paper talks about process mining as a reference to its core context or the development of algorithms that improves the functionality of the process mining tool.
  - EC2 The paper talks about process mining and/or ITSM as a side topic and not having it as core research area.

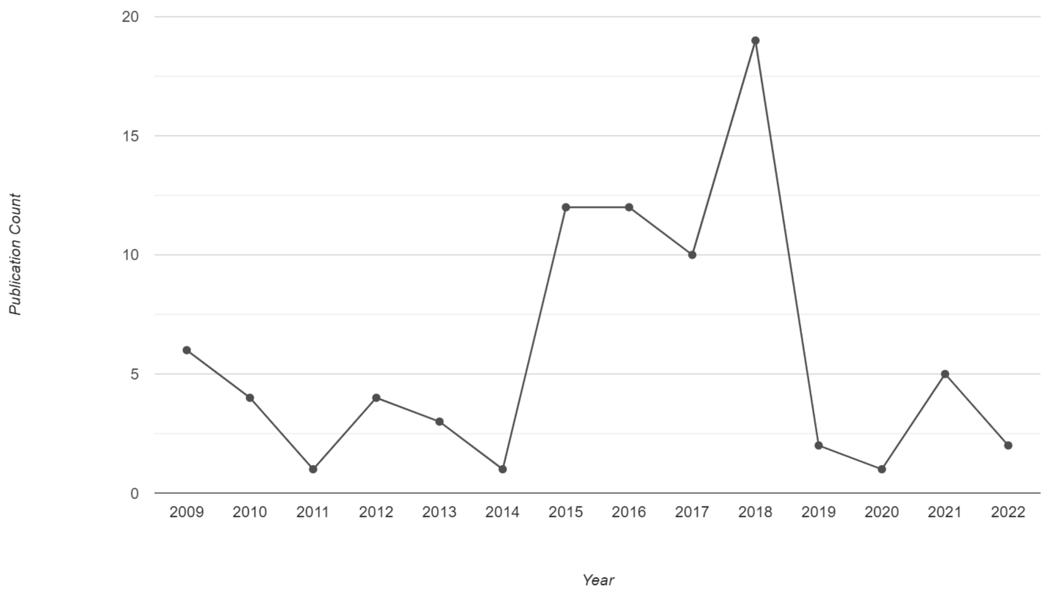

Figure C.1: Distribution of process mining literature studies in the service management line from 2009 until 2022

The 83 documents are subjected to the first phase of the review, where all documents are reviewed based on the title and the abstract. 24 relevant studies were found after applying inclusion and exclusion criteria during the second phase of the review for the extraction of data.

C.2 Critical appraisal of collected studies

Critical appraisal of the final set of 24 studies is conducted to make a remark on the quality of the collected studies, which will be used to articulate answers to the research questions (RQ1 to RQ6) of this research. The quality assessment questions were formulated concerning the research questions and applied to each publication. These questions helped us assess each study's quality and can be seen in Table C.1. These questions are inspired by considering the checklist and guidelines suggested in [51] and performing careful analysis on the collected literature studies. This allows us to judge the quality of the collected studies. For a critical appraisal of each study, each quality assessment question holds 1 point. Table C.1 describes the scoring criteria, such that if a study scores 1 for RQ1 and 0 for RQ2, it is still included. If a study attains an overall score of at least 7, the quality of the paper is considered high regarding this research, i.e. references corresponding to green coloured cells of the 'Total Score' column in Table C.2. For detailed quality assessment, see Table C.2. The studies have been categorized as 'INCLUDE' and 'EXCLUDE' in Table C.2. Upon critical appraisal, 20 studies were found relevant to be included for the extraction of data in the interest of this systematic literature review.

C.3 Data extraction process and synthesis strategy

Data extraction aims to accurately save the information from relevant documents to answer the research questions. It should be defined to eliminate the possibility of bias [51]. The Zotero bibliography management tool facilitates the analysis with a better structure and helps organize and inventorize the studies considered for this review. Zotero tool allows downloading a data extraction for each research paper. The model of this data extraction form is shown in Figure C.2.

Once the 24 relevant studies were selected, the following data extraction strategy was used. The keywords subsection of the documents is manually filled in depending on the information gathered while reading the document. A specific keyword from each paper showed its relevance to one of the research questions. To further reduce the probability of missing the representative information from publications that have not been included, a few papers were identified by using the strategy *snowballing* [98], i.e., a backward and forward search is conducted by analyzing the bibliographies and citations on the filtered set of papers. This snowballing approach also confirmed that the choice of databases for this research is valid in the context of this research. When papers have been thoroughly reviewed during the extraction phase, the defined checklists can help prevent literature with lower quality standards from corrupting the literature review results.

The strategy for data synthesis refers to determining whether the sources found provide qualitative or quantitative information [51]. The process for data synthesis is purely theoretical and qualitative. The data synthesizing is a simple collation and summary of the data extraction results to answer the research questions. In each of the analyzed studies, the lookup is to find the research's most critical findings, results, and limitations. The studies are analyzed and grouped into clusters manually, depending on how well they could respond to the research questions.

Research Question	**Assessment Questions**	**Independent Inclusion Score**
RQ1	QC1 Does the paper apply process mining to analyze the processes?	1
RQ2	QC2 Does the paper suggest process improvements by leveraging process mining technology and/or techniques? QC3 If the paper apply process mining just as an enabler for process discovery, does the study mention the next action steps for business process improvements?	1
RQ3 & RQ5	QC4 Does the paper explicitly mention any approach or methodology for the application of process mining? QC5 Is the proposed approach based on previously defined methodology or framework? QC6 Is the approach empirically evaluated or validated, i.e. by using a realistic example, a case study in a real world scenario, or any other empirical research method)?	2
RQ4	QC7 Does the paper talk about planning phase of process mining application? QC8 Does the paper talk about requirements such as data, roles, etc. for the application or adoption of process mining?	1
RQ6	QC9 Does the paper mention or suggest specific ITSM processes as candidates for process mining application? QC10 Does the study apply process mining on any specific ITSM processes? QC11 If yes, does the application of process mining have positive influence on the results obtained?	2

Table C.1: Criteria for Quality Assessment Scores

Reference	QC1	QC2	QC3	QC4	QC5	QC6	QC7	QC8	QC9	QC10	QC11	Total Score	Category
[35]	1	1	0	1	0	1	1	1	0	1	1	8	INCLUDE
[57]	1	1	1	0	0	0	0	0	0	1	1	5	INCLUDE
[66]	0	0	0	0	0	0	0	1	1	1	1	3	INCLUDE
[99]	0	0	0	0	0	0	0	1	0	0	0	1	INCLUDE
[59]	1	0	0	1	0	1	0	0	0	1	1	5	INCLUDE
[9]	1	0	0	1	0	1	1	1	0	1	1	7	INCLUDE
[100]	0	1	0	0	0	0	0	0	0	1	0	2	INCLUDE
[12]	1	1	0	1	0	1	0	1	1	0	0	6	INCLUDE
[101]	0	0	0	0	0	0	0	0	0	0	0	0	EXCLUDE
[64]	1	1	0	0	0	0	1	1	0	1	1	6	INCLUDE
[102]	1	0	0	1	0	1	0	0	0	0	0	3	INCLUDE
[68]	0	0	0	0	0	0	1	0	0	1	0	2	INCLUDE
[103]	1	0	0	0	0	0	0	0	0	0	0	1	INCLUDE
[61]	0	0	0	0	0	0	0	0	0	0	0	0	EXCLUDE
[104]	0	1	0	0	0	0	0	0	0	0	0	1	INCLUDE
[97]	1	1	0	0	0	0	j0	0	1	1	1	5	INCLUDE
[60]	1	1	0	0	0	0	0	1	1	1	1	6	INCLUDE
[105]	0	0	0	0	0	0	0	0	0	0	0	0	EXCLUDE
[14]	1	1	1	1	1	1	1	1	1	1	1	11	INCLUDE
[106]	0	0	0	0	0	0	0	0	0	0	0	0	EXCLUDE
[58]	1	1	1	1	1	1	1	1	0	1	1	10	INCLUDE
[6]	1	1	1	1	1	1	1	1	1	1	1	11	INCLUDE
[56]	1	1	1	0	0	0	0	0	0	0	0	3	INCLUDE
[107]	1	0	0	0	0	0	0	0	0	0	0	1	INCLUDE

Table C.2: Quality assessment according to the eleven quality criteria as mentioned in Table C.1

A case study on the business benefits of automated process discovery

Type	Conference Paper
Author	M. Puchovsky
Author	C. Di Ciccio
Author	J. Mendling
Editor	Guetl C., Rinderle-Ma S. Ceravolo P.
Abstract	Automated process discovery represents the defining capability of process mining. By exploiting transactional data from information systems, it aims to extract valuable process knowledge. Through process mining, an important link between two disciplines - data mining and business process management - has been established. However, while methods of both data mining and process management are well-established in practice, the potential of process mining for evaluation of business operations has only been recently recognised outside academia. Our quantitative analysis of real-life event log data investigates both the performance and social dimensions of a selected core business process of an Austrian IT service company. It shows that organisations can substantially benefit from adopting automated process discovery methods to visualise, understand and evaluate their processes. This is of particular relevance in today's world of data-driven decision making. © 2016, CEUR-WS. All rights reserved.
Date	2016
Language	English
URL	https://www.scopus.com/inward/record.uri?eid=2-s2.0-85009399312&partnerID=40&md5=906a657395c5ea4fbbce4ded02157baa
Extra	ISSN: 16130073
Volume	1757
Publisher	CEUR-WS
Pages	35-49
Proceedings Title	CEUR Workshop Proceedings
Date Added	9/2/2022, 1:56:04 PM
Modified	9/2/2022, 1:56:04 PM

Tags:

Data mining, Automation, Decision making, Administrative data processing, Automated process, Business benefits, Business operation, Business process management, Data driven decision, Enterprise resource management, Process knowledge, Process management, Transactional data

Notes:

Austria IT service company's process paper3.pdf (ceur-ws.org)

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cited By 5; Conference of 6th International Symposium on Data-Driven Process Discovery and Analysis, SIMPDA 2016 ; Conference Date: 15 December 2016 Through 16 December 2016; Conference Code:125463

Figure C.2: Zotero - Model of Data Extraction Form

C.4 Semi-Systematic Literature Review

This section discusses our SSLR approach to identifying and analysing the existing process mining methodologies. Identifying existing process mining methodologies besides the ones found during SLR is vital for this research as the goal can be achieved by mapping process mining approach to ITIL continual improvement practice. In particular, the search was for existing empirical studies of process mining methodologies in software engineering to answer the following research question: RQ4. The same approach as for SLR was adopted for this SSLR except for the choice of scientific databases, the search query, and an additional exclusion criteria. Additionally, the SSLR excludes the critical appraisal of the selected study. Table C.3 provides an overview of the chosen e-databases, search filters and count of documents the query retrieved for 2012-2022, and the search query adopted for this SSLR is
("process mining") AND ("methodology" OR "approach" OR "framework")

e-Database	Search within	Document Type	Total Documents
Scopus	Article title	Conference Proceeding, Journal	226
Web of Science	Title	Proceeding paper, Article	131
IEEE Xplore	All	-	488

Table C.3: Scientific Databases, Search Fields, and Document Type for SSLR

Firstly, the 845 documents were analyzed using the Zotero tool to remove duplicates and check this research's relevance. The title of the documents was manually skimmed, and only 74 document titles were found relevant to this SSLR. The 74 documents were reviewed again by skimming the abstract using the data extraction option provided by the Zotero tool, as seen in figure C.2. The inclusion and exclusion criteria were the same as the SLR with additional exclusion criteria - "to eliminate papers that talk about process mining methodology or approach only specific to certain industry and neglecting the usage for generic purpose". Table C.4 shows the list of documents that could potentially add value to this research.

No.	Title
1	Business process analysis in healthcare environments: A methodology based on process mining [73]
2	Process Diagnostics: A Method Based on Process Mining [69]
2	Process Mining for Six [70]
4	PM^2: A Process Mining Project Methodology [67]
5	Business Process Comparison: A Methodology and Case Study [71]
6	A Goal-Driven Evaluation Method Based On Process Mining for Healthcare Processes [45]
7	An Education Process Mining Framework: Unveiling Meaningful Information for Understanding Students' Learning Behavior and Improving Teaching Quality [75]
8	Question-Driven Methodology for Analyzing Emergency Room Processes Using Process Mining [72]
9	Material Movement Analysis for Warehouse Business Process Improvement with Process Mining: A Case Study [74]

Table C.4: List of papers retrieved using SSLR

C.5 Existing Process Mining Methodologies

C.5.1 Process Mining for Six Sigma Methodology

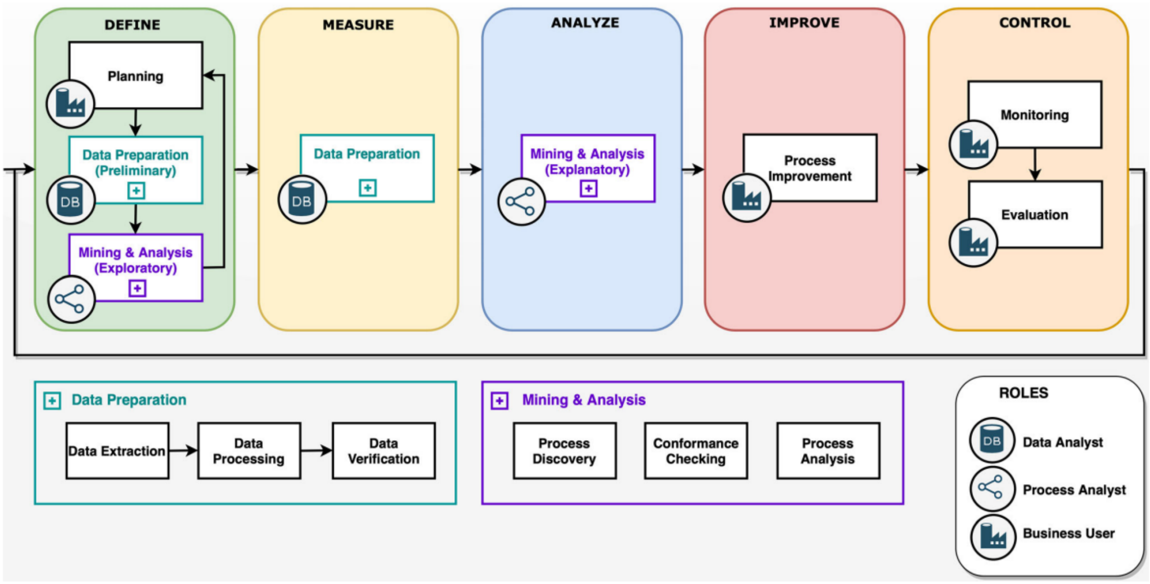


Figure C.3: PMSS Methodology [70]

C.5.2 Goal-Driven Evaluation Method based on Process Mining

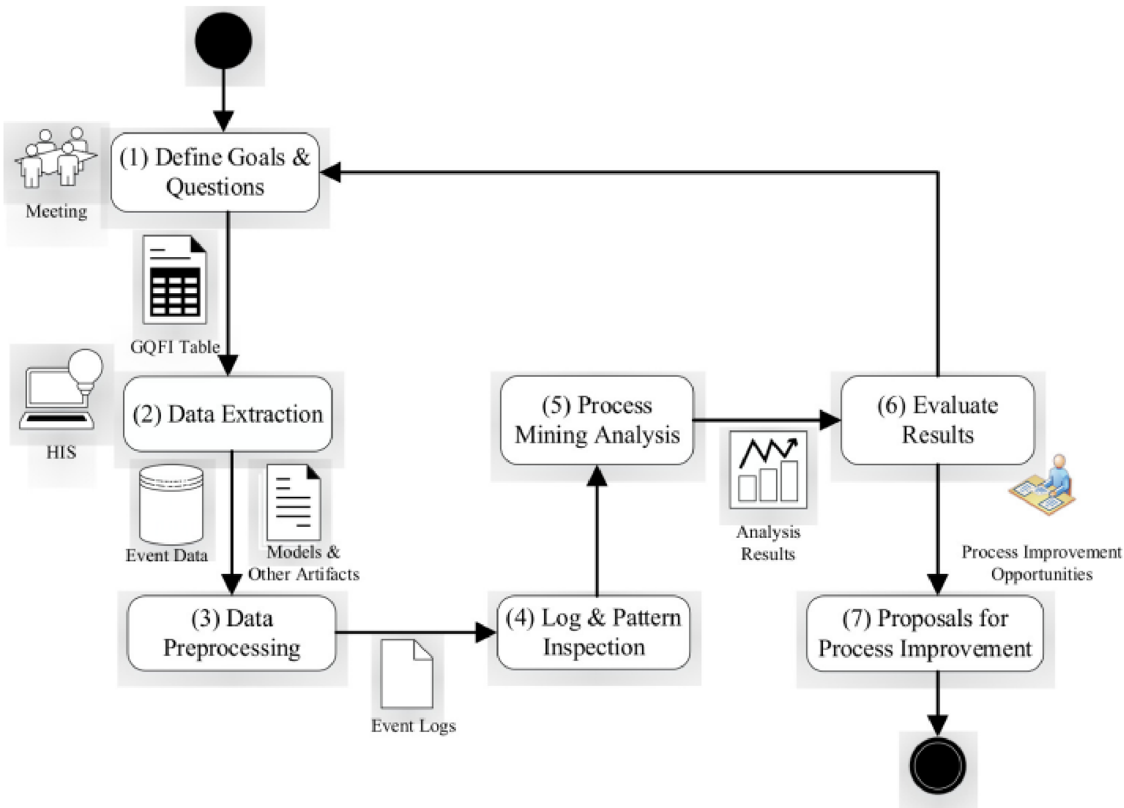


Figure C.4: Goal-Driven Methodology (Healthcare) [45]

C.5.3 L* Lifecycle Model

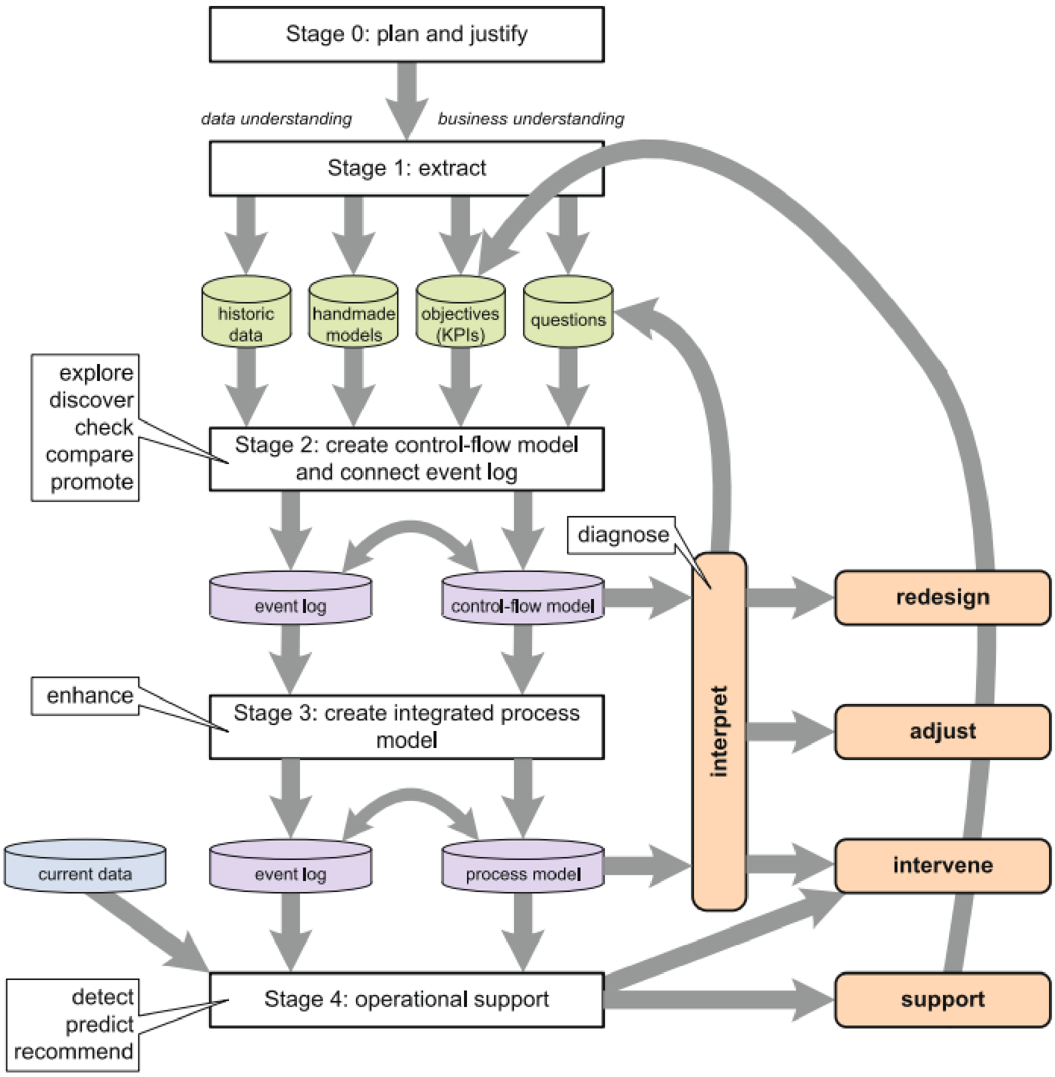


Figure C.5: Aalst's L* Life-cycle model consists of five stages viz. Stage 0: Plan and Justify, Stage 1: Extract, Stage 2: Create a control-flow model and Connect Event Log, Stage 3: Create integrated process model, and Stage 4: Operational support

C.5.4 Question-driven Process Mining Approach

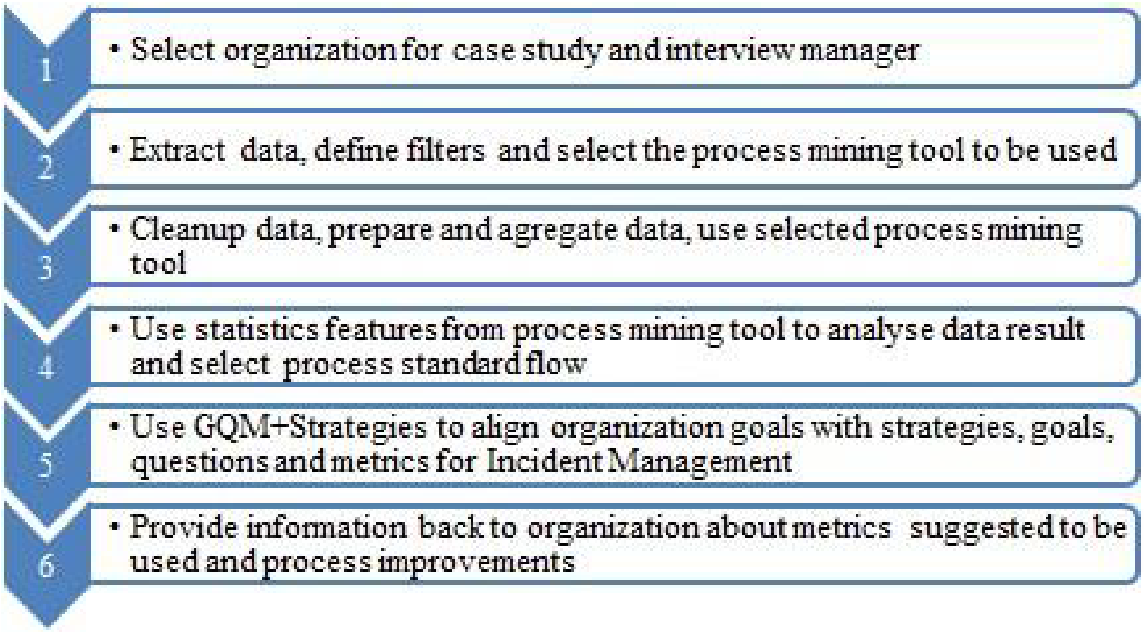


Figure C.6: Question-driven Process Mining Case Study

Appendix D

Framework Refinement - Overview of Expert Interview Process

This section of the report presents an overview of the expert interview process conducted to refine and attain the refined version of PM4CSI. Section D.1 describes the steps taken before interviewing domain experts. Then, section 5.1.2 presents information on the details of the interview. Section 5.1.3 and section 5.1.4 describe the information on the collection and analysis of the framework refinement interview data. Finally, section 5.1.5 presents the validity of findings obtained from the interview data.

D.1 Pre-interview Process

The following steps were taken during the pre-interview period to ensure a higher quality of results were obtained by conducting the experts' interviews.

1. Interviews were planned to be executed with an expert panel, mainly derived using Deloitte People Network, LinkedIn connections, and a snowballing approach, namely people with different functions who are active in the industry and the consultancy. An email/ direct message via LinkedIn was sent to domain experts. Multiple platforms were considered to ensure the diversity of the expert panel. Data were collected from different people and through diverse connections/platforms to have a generalized output by ensuring data triangulation. Triangulation of data enables multi-perspective results that will allow this research output to have reduced bias and increased credibility.
2. The interviews for extending and refining the framework were planned to take place in two rounds, approximately 60 minutes for each round.
3. As for the first round, the experts were selected solely based on their experience and knowledge of process mining. For the Second Round Interview, there were experts from the field of continual service improvement to ensure that the activities were mapped to the correct phases. The list of experts interviewed during the framework refinement and extension can be seen in Table A.2.
4. Due to the culture of working from anywhere after Covid-19, interviews were virtual, and Microsoft Teams was used predominantly to conduct interviews during this process. Hence, meeting invites were sent out to the selected participants and ensured that the recipients accepted each meeting invite.
5. A consent form was designed to ensure the participants' privacy, along with a description of the research. A consent form sample can be seen in Figure D.3.

6. Interview protocol was created to serve as guidance during the actual interview. The interview protocol has been reviewed and approved by the supervisors of this research. The detailed interview protocol can be seen in section D.1.2.
7. A reminder email was sent a week before the interview along with an infographic and ITIL manual for interviewees' preparation. A sample of the information provided to the interviewees can be seen in Figure D.4.
8. Otter.ai is a web-based software that empowers users with real-time transcription meeting notes that are shareable, searchable, editable, accessible and secure. For the experts' interview, a student subscription with Otter.ai for $13.59/month facilitated easy retrieval of transcription with less manual effort. However, the generated transcripts were reviewed to ensure correctness.
9. Personal calendar scheduled 15 minutes before each interview to ensure everything is set in place and to avoid technical difficulties during the interview.
10. It is essential to create infographics/ PowerPoint slides to conduct an interactive session with visual cues for improved clarity of the conversation. Microsoft PowerPoint Presentation was used to present the infographic and slides created for facilitating an interactive session. It is an excellent tool with features of innovative content creation, laser pointer, and markers, with a newly added option to present directly to Microsoft Teams within the application. Figure D.1 and D.2 shows the infographic presented during First Round Interviews and Second Round Interviews, respectively.

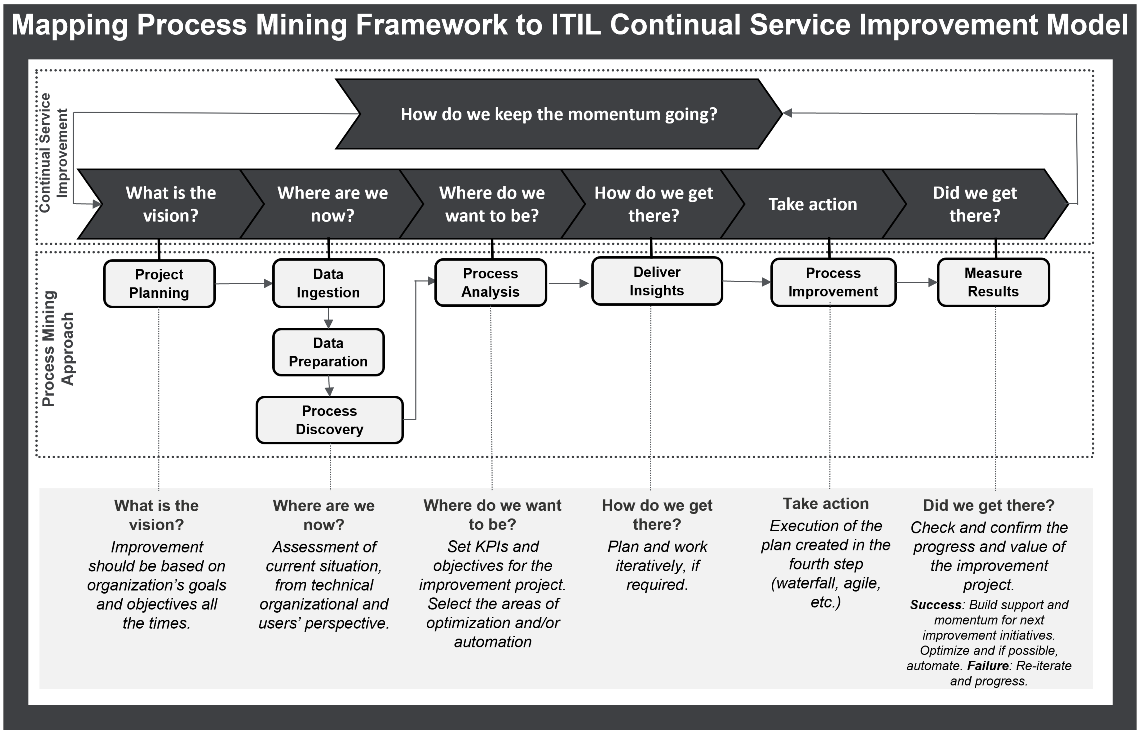


Figure D.1: Infographic used for First Round Interview

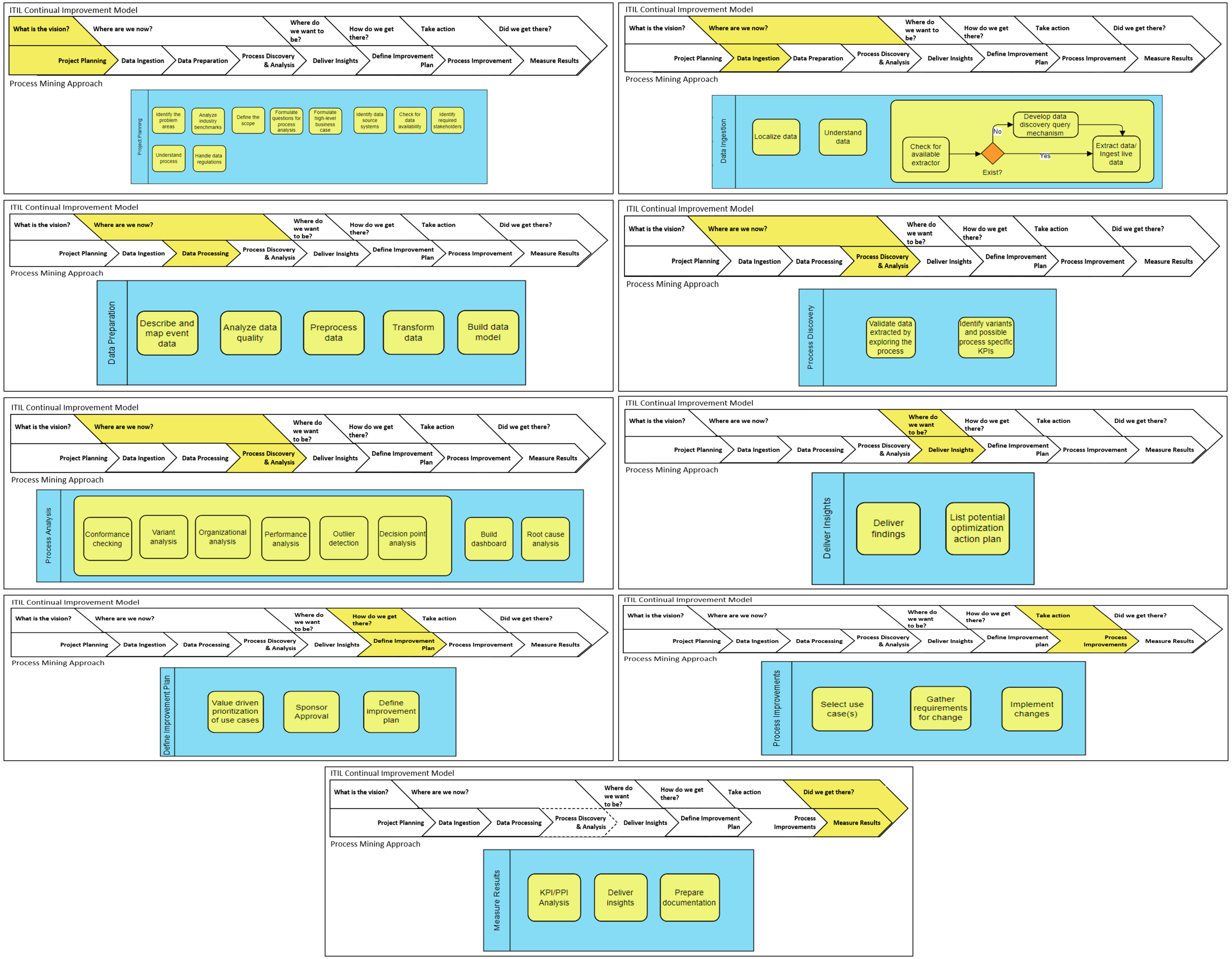


Figure D.2: Snips of Infographics used for Second Round Interview

D.1.1 Pilot Interview Results

Pilot interviews are essential before interviews with "real" interview participants. The trial interviews were conducted with two experts who were aware of and closely aligned with this research. Thus, the feedback from the sessions helped certify the interview protocol's reliability as a guiding instrument. Due to the extended series of interviews in less than four weeks and the time constraints of this research, no pilot sessions were conducted for Second Round Interviews. Hence the interview protocol has been reviewed in a round table session conducted informally with the same two experts.

Pilot for First Round Interview

The pilot interview started with an explanation of the interview design process followed in this research. All steps of the interview process were reviewed. The feedback was mostly positive. However, the critical suggestions were managing time efficiently and prioritizing the questions in the interview protocol. Prioritization of the questions allows the researcher to navigate the interview efficiently while not missing out on collecting critical data for analysis.

Pilot for Second Round Interview

The interview initiated with an explanation of the second version of PM4CSI. The parties agreed with the overall structure of the Second Round Interview Protocol. For the experts who participated in both rounds of interviews, the explanation of the research assignment was skipped. Nevertheless, the experts recommended re-using the content to remind the interviewees about the central context of the research. Additionally, the experts suggested seeking potential case studies and snowballing experts to validate the artifact at the interview's end.

D.1.2 Final Interview Protocol

The questions framed in the interview protocol were prepared to conduct semi-structured interviews with the domain experts. The questions were also colour coded in Microsoft Excel based on prioritization to use the minutes provided by each expert efficiently. Such prioritization allowed the initial minutes of the interview to focus on the most critical questions, followed by less important questions. Following are the interview protocols that acted as a guiding instrument for conducting both rounds of framework refinement interviews:

D.1.3 Grounded Theory Approach

This research used grounded theory to develop new theories and concepts based on the interview transcripts of the First Round Interview. The data collection process is known as theoretical sampling [86]. *Grounded theory* is a qualitative research method that aids the development of new theories based on the iterative collection and analysis of real-world data. It is a process of iteratively collecting and analyzing data to derive a new theoretical framework or knowledge. Grounded theory has been chosen specifically to synthesize data that would fill the gaps in the knowledge available in the academic literature of process mining applications in the improvement of processes in ITSM sphere.

The following considerations were specifically taken for conducting and reporting the grounded theory, as recommended by Stol et al. [85]:

- **What variant of grounded theory can be adopted?**
  The Straussian Grounded Theory [86] was selected because it promotes a streamlined approach to techniques that gather comprehensive and objective data. Based on the research question,

INTERVIEW CONSENT FORM

Participant's Name **Interview Date**

Project Research Title

Development of a process mining framework to improve IT service management processes

Description of the Project

- IT Service Management (ITSM) is a term that refers to the implementation, management, and delivery of quality IT services in the best possible way to meet business needs. It ensures that an appropriate mix of people, processes, and technology is in place to provide value to a business.
- In the ITSM industry, the initial process design varies considerably from the reality. Consequently, suboptimal processes create friction in business operations, impacting the cost, time, and quality of services. Such inefficient processes lead to poor customer satisfaction and a lack of compliance.
- ITIL v4 is a proven framework that provides best practices and guidance for ITSM. It also defines a continual service improvement model for improving ITSM initiatives. A data-driven approach such as process mining can eliminate gaps in the process design and improve process efficiency.
- The assignment of my thesis research is to apply process mining to improve ITSM processes. A process mining framework has been designed for this purpose that is adaptable to the ITIL v4 continual service improvement model.
- More on ITIL v4 can be found in the attachments from the email.

- I confirm that my participation in this research project is voluntary.
- I understand that I will not receive any payments for participating in these research interviews.
- I understand and agree for the interview meetings to be recorded. The recording serves to provide a detailed transcription for future analysis.
- I understand that most interviewees will find the discussion interesting and thought-provoking. I have the right to decline to answer any question or to end the interview.
- I confirm that the research interviews will last approximately 60 minutes.
- I understand that the researcher will not identify me by name in any reports using information obtained from this interview and that my confidentiality as a participant in this study will remain secure.
- I have read and understood the explanation provided to me.
- I have been given a copy of the consent form.
- I wish to review the notes, transcripts, or other data collected during the research interviews.
- I agree that the researchers may publish documents that contain quotations by me.

By signing this form, I agree to the terms indicated above.

Participant's Signature Researcher's Signature

Date: Date:

Figure D.3: Sample Consent Form for the Interviewees

Palanikumar, Charumathi

Subject:	Information for interviewee - Sample
Location:	Microsoft Teams Meeting
Start:	vr 21-10-2022 10:00
End:	vr 21-10-2022 10:25
Recurrence:	(none)
Meeting Status:	Meeting organizer
Organizer:	Palanikumar, Charumathi
Required Attendees:	Palanikumar, Charumathi

PROCESS MINING TO IMPROVE IT SERVICE MANAGEMENT PROCESSES- FIRST ROUND INTERVIEW DETAILS

Dear X,

I hope this email finds you well.

Once again, I thank you for volunteering to participate in my research interviews. I have attached a one-pager describing our interview's purpose and content. Additionally, I have added the ITIL v4 foundations manual for your reference.

Project/ Research title
Development of a process mining framework to improve IT service management processes.
Description of the project

- IT Service Management (ITSM) is a term that refers to the implementation, management, and delivery of quality IT services in the best possible way to meet business needs. It ensures that an appropriate mix of people, processes, and technology is in place to provide value to a business.
- In the ITSM industry, the initial process design varies considerably from the reality. Consequently, suboptimal processes create friction in business operations, impacting service cost, time, and quality. Such inefficient processes lead to poor customer satisfaction and a lack of compliance.
- ITIL v4 is a proven framework that provides best practices and guidance for ITSM. It also defines a continual service improvement model for improving ITSM initiatives. A data-driven approach such as process mining can eliminate gaps in the process design and improve process efficiency.
- The assignment of my thesis research is to apply process mining to improve ITSM processes. A process mining framework has been designed for this purpose that is adaptable to the ITIL v4 continual service improvement model.

Note

- The research is conducted by the University of Twente as **public, academic research**. The interview results will be solely used as a **data source for my M.Sc. thesis**.
- The only personal information in my thesis report will be **your job title and years of experience**. However, if any of the two is considered private information, it can all be **anonymized**. Additionally, during our interview, if any sensitive information is shared, it will not be documented. I will send the transcript of the interview to you for your acknowledgement.
- The interview will take up around **one hour of your time**.
- I **request for the meetings to be recorded**. The recording will **provide a detailed transcription** for future analysis and **will be deleted** shortly after our interview.

Looking forward to having interesting conversations with you!

Best Regards,

Charumathi Palanikumar
Graduate Intern – Business Information Technology
University of Twente

Microsoft Teams meeting
Join on your computer, mobile app or room device
Click here to join the meeting
Meeting ID: 382 143 *** ***
Passcode: ******

Figure D.4: Sample email invitation along with interview information

- **What is the expected expertise of the interviewee to be studied?**
  The interviewees were selected after carefully analyzing their experience and profile to include process mining and/or ITSM as their core profession.
- **What is the purpose of conducting the interview?**
  The purpose of conducting the interview is to understand the methodologies by which process mining projects occur in the industry. By gaining such knowledge, the framework to be developed will not only fill the identified research gap found during the research's SLR but also adds practical value to the artifact in design.
- **What topic areas should be reviewed in scientific literature before and during the study?**
  (i) The state-of-the-art knowledge on how process mining has been applied in the field of ITSM for service process improvements; (ii) Approach taken in the academic research to conduct a process mining project for assessing and improving ITSM process.
- **Did the generated theory integrate back into the literature?**
  The theory generated from the data collected during the framework refinement interviews had positive feedback over the first version of PM4CSI. However, the ambiguity of the activities and requirements in each process mining step has been unified into the framework as refined PM4CSI. The refined PM4CSI blends into the literature and provides a clarified approach by the evolution contributed by the output of this research.
- **How might the author's or the interviewees' biases, perceptions, background and beliefs affect the analysis?**
  Reliability checks have been done through all the steps of the framework refinement interview process, which is an essential part of the research to build a new conceptual framework.
  Interviewer/author/researcher's Bias: The interviewer's process of understanding the current knowledge in the research topic and building the first version of PM4CSI might be a threat to validity if the interviewer influences the participant or drives the expert interviews in the direction she envisions the refined PM4CSI. Hence such researcher bias has been handled by supervisors' reviewing the interview protocol and conducting pilot interviews to avoid biased inquiries during the interviews. During the analysis of collected data, grounded theory was considered to carefully categorize, analyze and synthesize the data to avoid confirmation bias. Also, the codes under which the data were highlighted and categorized were reviewed by peers through a *critique session* to make the codes sensible to the research context and exclude any pre-assumptions on the data collected.
  Interviewee's Bias: To avoid participant bias, a semi-structured interview was chosen as qualitative data research method so that questions framed can be open-ended and inquiry-driven to build a "natural" flow of conversation. Few participants have worked with only one process mining tool, i.e., Celonis. To ensure validity and generalizability, data were collected from people across different organizations, locations, experience with different process mining tools, and two rounds of interviews for data saturation. Further, the PM4CSI framework has been used in case studies to show the framework is tool agnostic.
- **What data was collected?** The data collection is the information provided by the experts during the interviews in the form of recording, which then was converted into refined transcripts for analysis. Also, the data collected included documents not cited or added as references in this research due to confidentiality terms.
- **Who collected and analyzed the data? How was this conducted?** The author, the researcher of this thesis project, collected the data. The data collection, analysis, and

Figure D.5: Word Cloud for First Round Interview Data

synthesis process have been presented in this section and D. The Appendix D also describes how the core category emerged and its impact on the analysis, storage of data and handling of the volume and heterogeneity of data.

Straussian grounded theory approach [86] was followed in the analysis of qualitative data collected during the interview. Open coding, axial coding and selective coding are steps in the grounded theory method of analyzing qualitative data. Before the coding phase, it is essential to gather qualitative data by transcribing the interview minutes, performed as the first data analysis phase. The first step is open coding, where the transcripts are broken into discrete excerpts, adhering to the participants' terms. Such discrete parts are created as codes and are labelled. Open coding opened up new theoretical possibilities when engaging with qualitative data by uncovering concepts and categories [86]. The next step is axial coding, which helps find the codes' relationships. The codes created during open coding phases are analyzed and based on their connections, the codes are grouped into categories. The categories serve as axes that tie the codes together. The final step is selective coding, where all categories are connected to a core category, representing our research's central focus. The core category forms the basis for the final theory. Notes and memos were added during open coding and axial coding phases, enabling the researcher to discover the relationship between the core category and other categories.

Semi-Structured First Round Interview Protocol
Introduction
Introduce each other and brief the purpose of the interview *****Permission***** Before we continue, I would like to ask your permission to have this interview recorded. The recording serves to provide a detailed transcription for future data analysis. The recording will be deleted shortly after the interview. *****Background***** Firstly, it is important to mention that this research is conducted by the University of Twente as public, academic research. The interview results will be solely used as a data source for my master's thesis. The only personal information documented will be your job title and years of experience. However, if any of the two is considered private information, it can all be anonymized. Additionally, if any sensitive information is shared, it will not be documented. The transcript of this interview will be sent to you for your acknowledgement. The interview will take up around one hour of your time. *****About Interviewee***** 1. Could you please introduce yourself to me? 2. Can you brief me about your professional background? How long have you been active in your current role? What are your tasks in your current role? Could you elaborate upon your current background in working on process mining projects? 3. What is/was your role in process mining projects? 4. Who designed the approach that was used in those projects? [Ask for a whitepaper or literature] What was the goal? [Process improvement or process analysis]
Infographic Presentation
Explain for the context of the research assignment, ITIL Continual Improvement Model, and the brief in a sentence or two about the process to design the first version of PM4CSI. *****Show the first version PM4CSI Framework***** 1. Do you agree these are the main steps to leverage process mining technology in continual service improvements? 2. Would you add/modify/remove any?

***Contd: Semi-Structured First Round Interview Protocol**
Phase Analysis
Discuss each phase in detail with the following question 1. What is the goal of this phase? 2. What are the sub-tasks/activities? 3. What are the prerequisites/ inputs for this phase? [Process characteristics? Data format? Data quality? Data discovery?] 4. Which stakeholders are necessary, and what are their responsibilities in this phase? 5. What is the estimated time/ effort needed to complete this phase successfully? 6. What do you think is the important factor for successful completion and key challenges
Effect Questions
1. Do you use any specific PM framework?/ Are you familiar with any other process mining methodologies, such as $PM\hat{2}$? 2. Have you seen any other data-driven solutions that reduces manual BPI work to improve processes?
Relevance and Demand
1. Have you struggled in any use case? If yes, what was the learning to avoid repeating it in future projects? 2. Do you think developing a standardized methodology for process mining is useful to improve ITSM processes?
End Card
1. Is there any literature available on this topic? It would be nice if you could share strategy papers, meeting memos, or archival documents that can help us understand the methods and requirements for process mining applicability. 2. Do you have any questions or additional remarks regarding the topic? 3. Any feedback or recommendations for future interviews, if any?
*****Express gratitude; Interview ends, end the recording, ensure it is stored and saved properly*****

Semi-Structured Second Round Interview Protocol
Introduction
Same content from the First Round Interview Protocol to be used. **For experts who participated in First Round Interview, greet and explain the purpose of the interview. The rest of this section was skipped.*
Infographic Presentation
Explain for the context of the research assignment, ITIL Continual Improvement Model, and the brief in a sentence or two about the process to design the second version of PM4CSI. *****Show the second version PM4CSI Framework***** 1. Do you agree these are the main steps to leverage process mining technology in continual service improvements? 2. Would you add/modify/remove any?
Phase Analysis
Review each phase and pose questions to ensure if the activities, pre-requisites, outcomes, stakeholders involved in each phase is accurate and as executed in practice.
Effect Questions
Same content from the First Round Interview Protocol to be used. *Skipped for experts who participated in First Round Interview
Relevance and Demand
Same content from the First Round Interview Protocol to be used. *Skipped for experts who participated in First Round Interview
End Card
Explain the process planned for the validation of the refined PM4CSI and request for potential case studies if available and snowballing experts for evaluation.
*****Express gratitude; Interview ends, end the recording, ensure it is stored and saved properly*****

Code Name	Description	Files	References
Framework	Framework node contains the first impression of the process mining framework V1.0. The child nodes contain the information related to the process mining approach including required modification, involved stakeholders, pre-requisites and so on, aggregated from all the interviewees	9	295
1.What is the vision	The parent node for all the information relating to the first step of ITIL Continual Improvement Model	9	95
1. Changes	What are the changes required in the designed framework?	3	14
1. Pre-requisite	What are the required inputs for first step?	6	8
1. Process characteristics	What are the relevant process characteristics for process mining feasibility	7	12
1. Project planning	What are the activities that take place during the project planning phase?	7	25
1. Stakeholders	Who are the stakeholders involved in the project planning phase?	9	25
1. Stop	When does the project planning stop? When does we reach a point to not proceed with the improvement project using project mining	1	1
2. Where are we now	The parent node for all the information relating to the second step of ITIL Continual Improvement Model	9	84
2. Changes	What are the changes required in the designed framework?	7	16
Data Quality	Data regarding the quality of data required for process mining application	4	5
2. Data Ingestion	Experts' opinion regarding the data ingestion phase	9	32
2. Data Format	Experts' opinion regarding the data format for process mining tool	8	11
2.1 Stakeholders	Who are the stakeholders involved in the data ingestion phase?	2	3
2. Data Preparation	Information regarding data preparation phase	6	14
2. Pre-requisite	What are the prerequisites for second step?	2	3
2. Process Discovery	Information regarding process discovery phase	4	8
2. Stakeholders	Who are the stakeholders involved in the second step?	5	11
3. Where do we want to be	The parent node for all the information relating to the third step of ITIL Continual Improvement Model	9	33
3. Changes	What are the changes required in the designed framework?	3	6
3. Pre-requisites	What are the prerequisites for third step?	2	2
3. Process Analysis	Information regarding process analysis phase	7	18
3. Stakeholders	Who are the stakeholders involved in the third step?	5	7
4. How do we get there	The parent node for all the information relating to the fourth step of ITIL Continual Improvement Model	8	24
4. Deliver insights	Information regarding deliver insights phase	8	21
4. Stakeholders	Who are the stakeholders involved in the fourth step?	3	3
5. Take Action	The parent node for all the information relating to the fifth step of ITIL Continual Improvement Model	8	22
5. Process enhancement	Information regarding process improvement phase	8	17
5. stakeholders	Who are the stakeholders involved in the fifth step?	4	5
6. Did we get there	The parent node for all the information relating to the sixth step of ITIL Continual Improvement Model	5	6
6. Measure Results	Information regarding measure results phase	3	4
6. Stakeholders	Who are the stakeholders involved in the sixth step?	1	1
7. How do we keep the momentum going	The parent node for all the information relating to the seventh step of ITIL Continual Improvement Model	8	15
7. Continual or RPA	Information regarding how to keep the momentum going?	7	10
future work	Ideas for future work	2	2
Learning	The parent node for all the information relating to the other learnings from the interviews	7	10
0. Process Mining Vs BI	Comparison of other process analysis approach	7	16
Relevance	Insights on the relevance of this research	4	4
Success factor	Information regarding success factors of a process mining project	7	19
Time Effort	Information regarding time and effort required for a process mining improvement project	5	10

Table D.1: NVivo Codebook - *White colored rows correspond to quoting performed during the coding phase, Yellow colored rows correspond to axial codes, and Green colored row corresponds to selective code which forms the central focus of the interview*

The Nvivo application has been used as a qualitative data analysis tool for the next phase of transcript data analysis. The rationale behind using Nvivo software includes the following: (i) Nvivo provides a platform to organize and analyze unstructured information and media and visualization capabilities; (ii) Both rounds of interviews were conducted ten days apart, and qualitative data analysis software accelerated the process of transcripts' analysis. The transcripts have been quoted under codes that corresponded with the interview protocol (refer section D.1.2). Quoting the data collected into respective codes served to aggregate all data corresponding to answering the relevant research questions. Every interview transcript was analyzed at the earliest to keep the memory of essential takeaways like participants' gestures and emotions. All three coding steps were conducted iteratively to build a new theory in our collected transcripts. The iterations only stopped when there were no further modifications and the theory had well-thought-out propositions. Nvivo software was used to conduct each loop of open-axial-selective coding. The coding method ensured that codes for each category were identified and collated accordingly. The codes were revisited during the analysis of every single transcript. New codes were added to data that did not fit the category of codes created during the analysis of earlier transcripts.

The NVivo tool maintained a codebook, and the final coding schema is presented in Table D.1, and relevant quotes for each category of codes are saved. In Table D.1, White-colored rows show the data gathered during the iterative analysis of open codes to be aggregated into categories, yellow-coloured rows show axial codes which establish relationships between the identified concepts and categories, and green-coloured row shows the selective code that collectively forms a theory. Consequently, raw data from interview transcripts and confidential archival documents shaped the theory into refined theoretical hypotheses. Nvivo also allowed visualizing the coding percentage contributed by the participants in each category as shown in Figure 5.4. Additionally, as shown in Figure D.5, a word cloud enabled the visualization of the highest frequency words within the core category in a single glance.

Appendix E

Framework Validation

E.1 Case 1: Public Data - Microsoft Power Automate

Data connection methods offered by Process Advisor

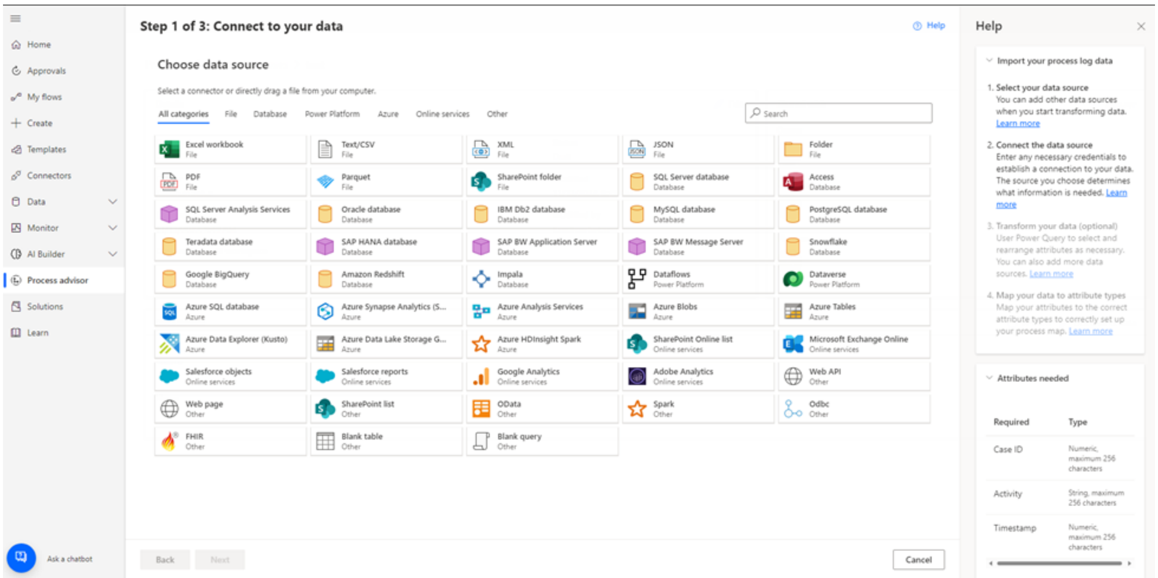


Figure E.1: Process Advisor - Data Connection UI

Case-level and event-level assignment of attributes

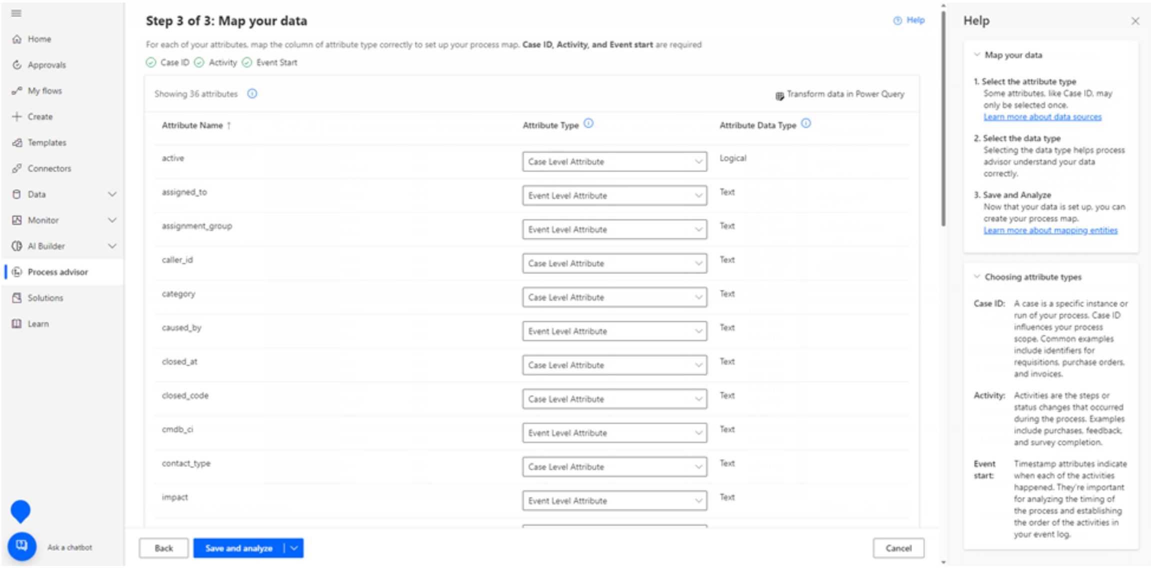
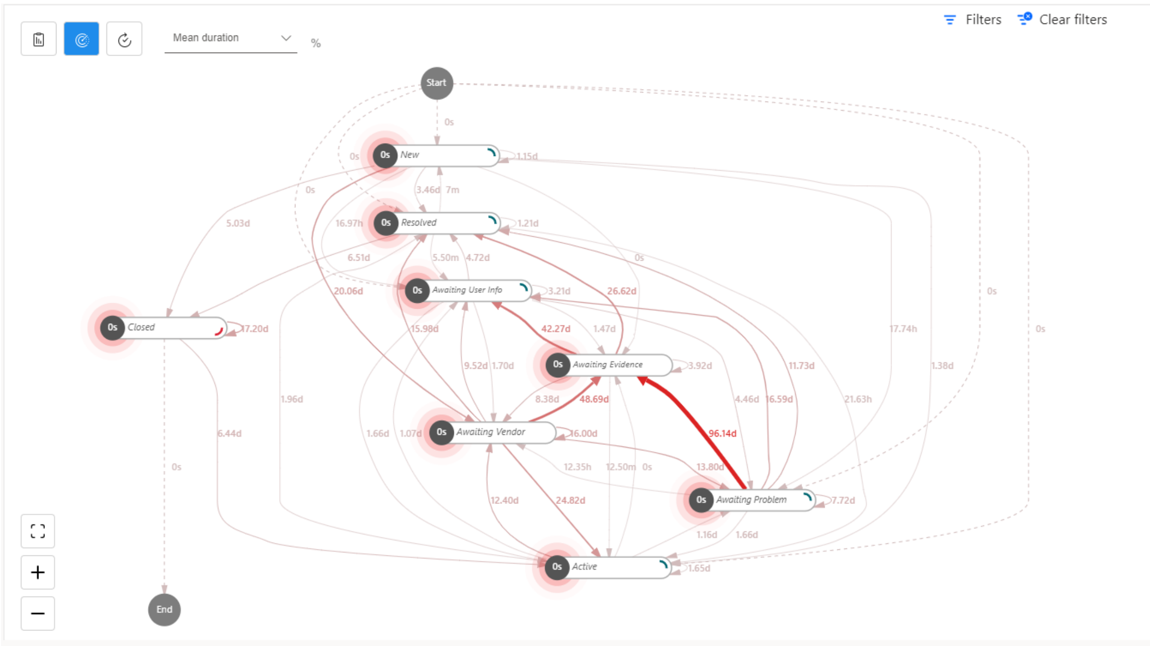


Figure E.2: Assignment of Attributes to Case-Level and Event-Level - Sample

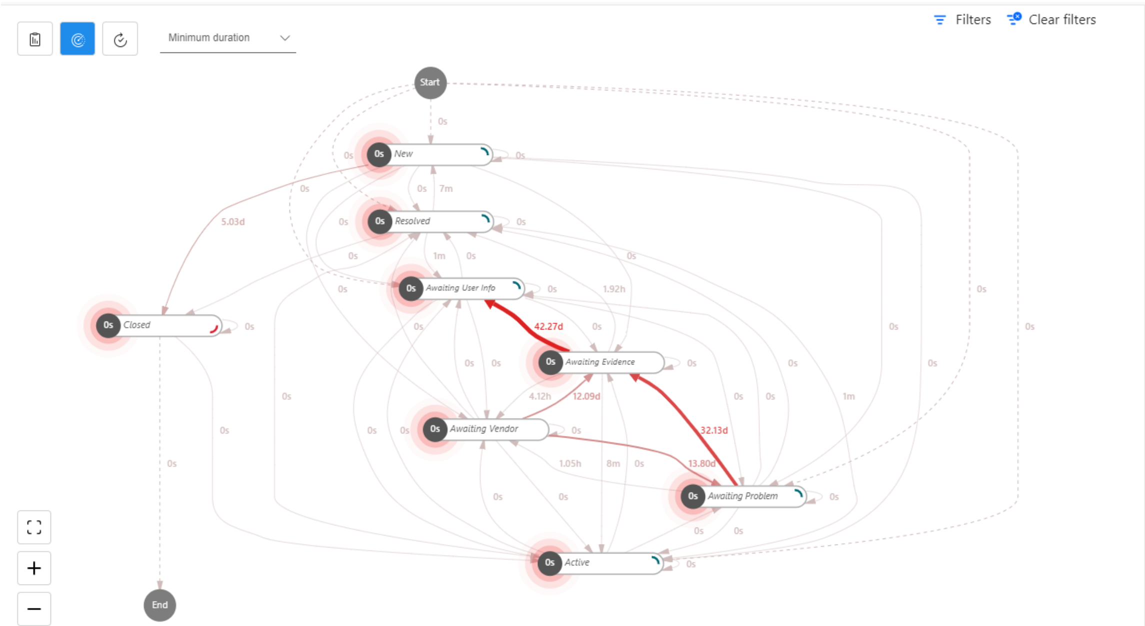
Process Discovery and Analysis

Figure E.3: Process Variants Explorer

Figure E.4: Performance analysis

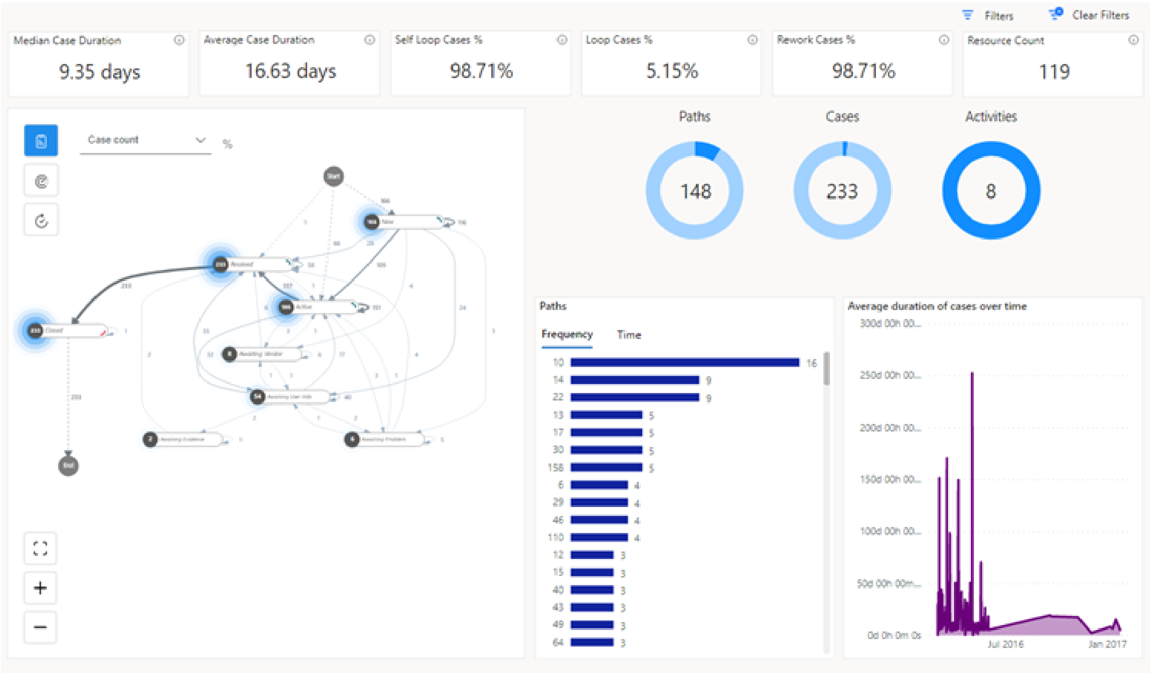


(a) Performance - Mean Duration

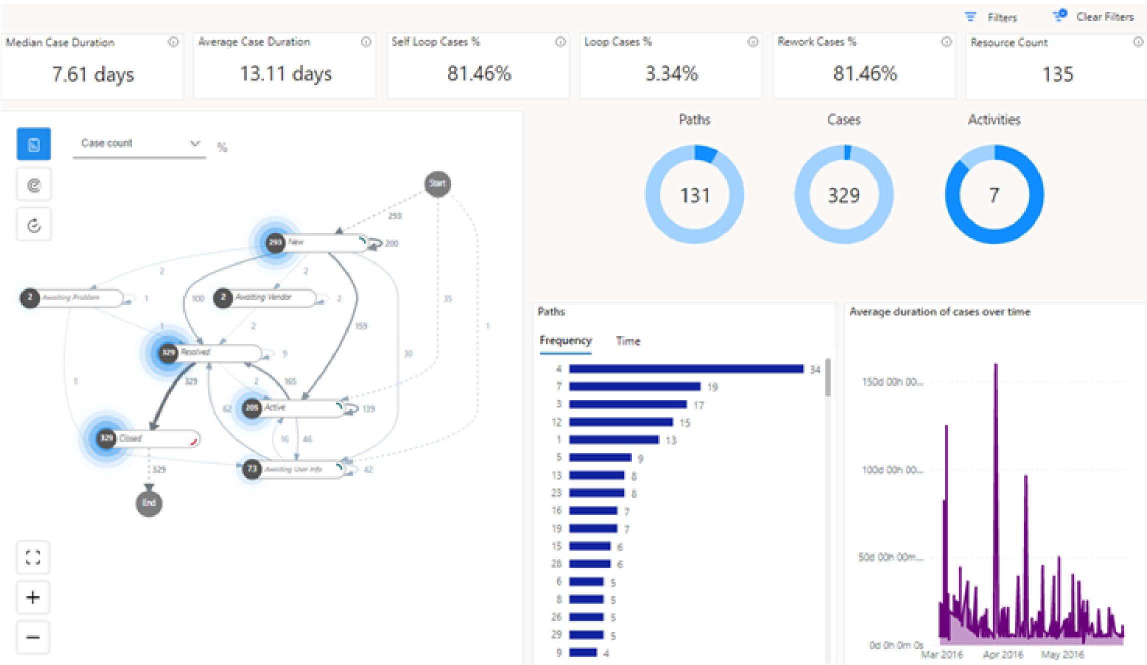


(b) Performance - Minimum Duration

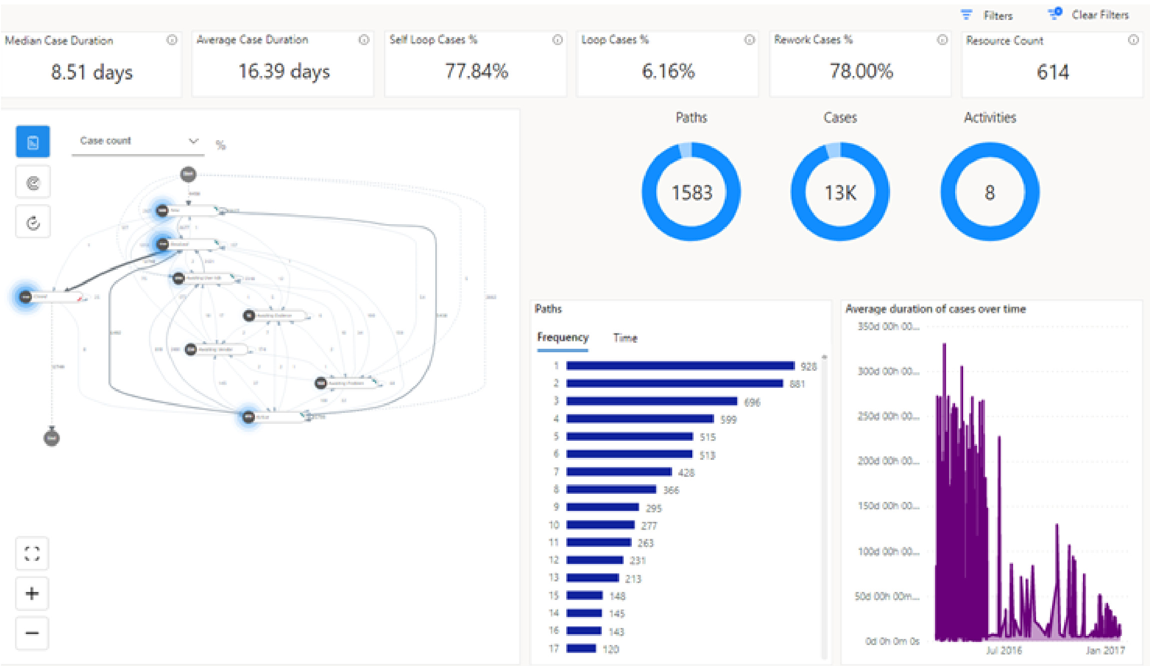
Figure E.5: Dimensional analysis based on incidents' priority



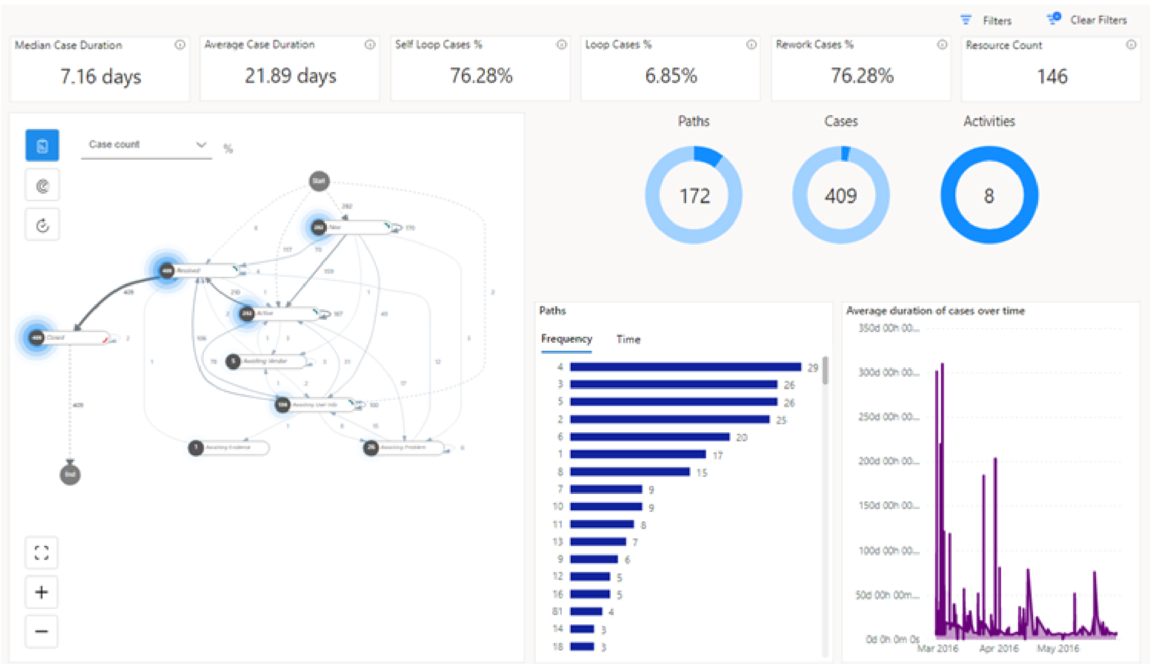
(a) Critical Priority Cases



(b) High Priority Cases



(a) Moderate Priority Cases



(b) Low Priority Cases

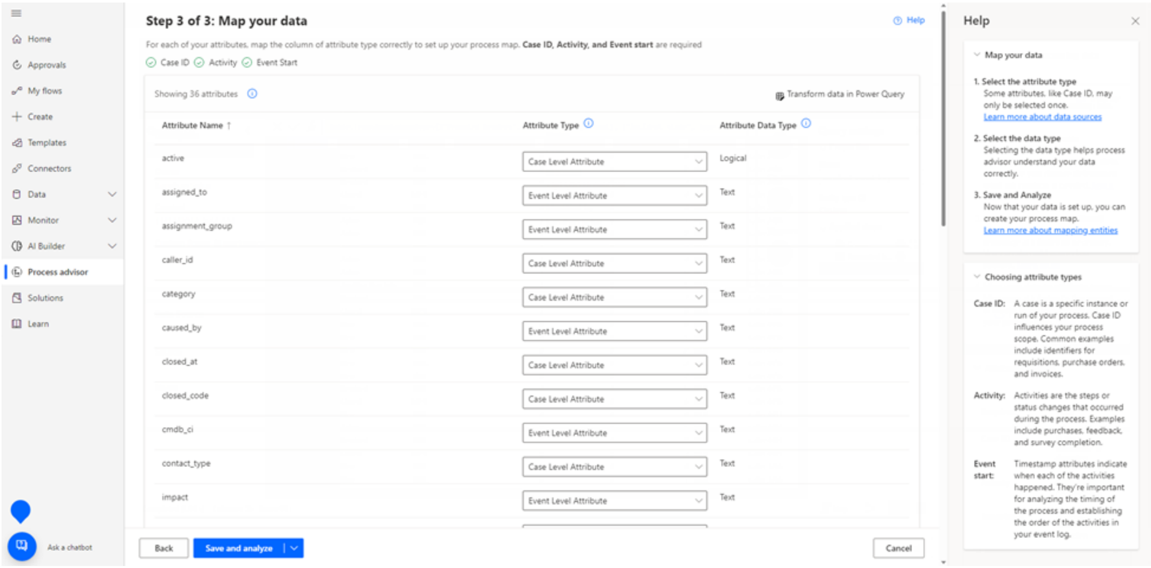


Figure E.6: Analysis from Resource Perspective - Sample

E.2 Case 2a: Leading Medical Imaging Equipment Supplier - Process X-Ray

Not added to this report due to confidentiality agreement with the company ABC.

E.3 Case 2b: Leading Medical Imaging Equipment Supplier - Celonis

Not added to this report due to confidentiality agreement with the company ABC.