

Identifying root causes of internal delays in the cleaning tool fulfillment process and proposing improvement opportunities

University of Twente

Élodie Thomas

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Title

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Author

Élodie Thomas

S2853574

e.z.m.thomas@student.utwente.nl

University of Twente

Industrial Engineering and Management

P.O. Box 217

7500 AE Enschede

Faculty of Behavioural, Management and Social Sciences (BMS)

Supervisors University of Twente

dr. ir. J.M.J Schutten (Marco)

dr. B. Roorda (Berend)

ROSEN Europe B.V.

Zutphenstraat 15

7575 EJ Oldenzaal

Supervisors ROSEN Europe B.V.

Mark Buil

Petra Hendrikse

Preface

Dear reader,

With this thesis I finish my Bachelor's program in Industrial Engineering and Management at the University of Twente. Over the past months, I researched the cleaning tool fulfillment process at ROSEN Europe B.V., with the aim of finding the main root causes of delays and finding suitable improvements.

I would like to thank ROSEN for giving me the chance to conduct this research. A special thanks goes to my supervisors at ROSEN, Petra Hendrikse and Mark Buil, for their guidance, support, and for making me feel welcome during my time there. I am also grateful for all the other employees at ROSEN that helped me to bring my research to a good end. Everyone always wanted to help and was always willing to answer another of my questions.

I would also like to thank Marco Schutten for his critical view, ideas, and feedback on my thesis. This helped me to improve my thesis and made it much more complete and useful. Furthermore, I would like to thank Berend Roorda for being my second supervisor.

Lastly, I want to thank my family and friends for their support and feedback. Without them, the period of conducting this thesis would have been much more difficult.

I hope this thesis is useful for ROSEN and shows what I have learned in the past years of my studies. I hope you enjoy reading it!

Élodie Thomas,
Enschede, November 2025

Management summary

ROSEN Europe B.V. designs and assembles custom-made tools that help clean and inspect pipelines. Before an inspection tool can be used, the pipeline must first be cleaned with a cleaning tool. These cleaning tools are prepared in the Oldenzaal workshop, where reusable bodies are equipped with client-specific parts. This process, known as the cleaning tool fulfillment process, involves several departments, from project management and supply chain to the assembly in the workshop.

Although external delivery deadlines are usually met, the process often faces internal delays. These delays reduce efficiency, increase complexity, and cause frustration among employees. 35.5% of cleaning tool orders are delivered with an internal delay. Based on this problem, the company wants to know how these delays can be prevented in the future.

The aim of this research is therefore to analyze and improve the cleaning tool fulfillment process to reduce preventable internal delays. This research combines process analysis and root cause analysis. The process visualizes the workflow using Business Process Model and Notation (BPMN), giving a clear overview of how departments interact and where certain problems occur. Semi-structured interviews with seven employees from six different departments provided further insight into recurring issues. These findings structure and analyze the problems using Fishbone Diagram and the Five Why analysis.

The analysis identified three main problems that together explain most of the internal delays. Each of the main problem areas has its own root cause:

1. Parts are not available when required
 - a. Cleaning tools are perceived as less critical than inspection tools
 - b. Tool Preparation Sheets (TPS) are often customized too late
2. Incorrect parts are delivered
 - a. Pipeline data often incomplete or incorrect
 - b. High reliance on manual data entry and checks
 - c. Two-eyes principle
3. Workshop tasks are unable to be executed efficiently
 - a. Lack of priority rules in assembly
 - b. Parts on returned tools are not registered
 - c. Knowledge and tasks are concentrated in one employee

In addition to these problems and their root causes, several cross-cutting issues were found that contribute to all three problems.

1. Weak prioritization of revisions
2. Unstrategic order acceptance
3. Gauging run date is not archived systematically

Based on these findings, we propose ten improvement opportunities. These include:

1. Formalizing the role of cleaning tools in project kick-off meetings, ensuring early alignment and the timely start of procurement activities.
2. Prioritization rules for TPS customization that consider both due dates and the complexity of the tool in question, preventing late orders.
3. Formal data verification step at project start to improve data accuracy before it already enters the project execution phase.
4. Standardized templates with built-in controls to reduce manual entry errors and improve reliability.
5. Introduce clear assembly priority rules, ensuring assembly only starts once all parts are available, reducing interruptions and change orders.
6. Register parts of returned tools to improve inventory accuracy.
7. Training and knowledge transfer, to minimize dependency on one person and improve flexibility in the workshop.
8. Standardize revision handling to avoid confusion between different versions of TPSs.
9. Strategic order acceptance to align sales commitments with their capacity in the workshop.
10. Systematic archiving of gauging run data to ensure data is not getting lost but saved for future use.

These improvements provide clear opportunities for implementation in their process. The three phases to implement these improvements are, strengthening the foundation, improving the collaboration and building lasting reliability.

By first structuring the process more clearly, then finding the root causes, and finally proposing improvement opportunities, ROSEN can reduce their internal delays and build a foundation for even more and continuous improvement.

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List of Abbreviations

APS	Actual Process Start
BPM	Business Process Management
BPMN	Business Process Modeling and Notation
FT	Final Test Technician
ILI	In-Line Inspection
MT	Mechanic Technician
PM	Project Manager
RCA	Root Cause Analysis
RDA	Real Date of Availability
SC	Supply Chain
SDA	Scheduled Date of Availability
SDR	Scheduled Data of Requirement
SL	Schedule Lead
STA	Start Target Date
SOP	Shop Operations Coordinator
SC	Supply Chain
TDA	Target Date of Availability
TC	Tool Customizer
TL	Tool Lead
TPS	Tool Preparation Sheet
WOV	Work Order Review
WL	Workgroup Lead

1. Introduction

This thesis presents the research that we conduct at ROSEN Europe B.V. to obtain the Bachelor's degree in Industrial Engineering and Management. This first chapter introduces the research. Section 1.1 introduces the company, giving a global overview of what the company entails and what their main activities are. Section 1.2 provides an explanation of the problem context. This section defines the research problems and their relations, together with the gap between the norm and reality. Section 1.3 discusses the research questions for this research and the deliverables. Finally, Section 1.4 gives the research design by explaining the outline of the research per chapter.

1.1 Company description

The ROSEN Group was founded in 1981 in a town in Germany called Lingen. With now more than 40 locations, ROSEN has grown into a worldwide leader in ensuring the safety and reliability of pipelines. The company inspects pipelines to prevent big complications and enables the pipelines to be able to be used for a longer period of time. The company provides tools for industries such as the oil and gas industry.

ROSEN designs and produces tools that clean and inspect pipelines with diameters ranging from 6 to 56 inches. Each tool has different requirements coming from the client. The inspection of the pipelines can only be conducted when the pipeline is clean enough to detect potential issues inside the pipeline. This otherwise can affect the reliability of the inspection. A cleaning tool guarantees that the pipeline is thoroughly cleaned by removing debris, buildup, or residues that the substance flowing through the pipeline can cause.

This report focuses on ROSEN Europe B.V. in Oldenzaal, from now on referred to as ROSEN, and focuses on the process and challenges related to cleaning tools. These tools are crucial in preparing the pipeline for its inspection. The number of cleaning tool runs a pipeline needs depends on several factors. Examples of these factors are the characteristics of the pipeline and the type of substance that flows through it, such as oil or gas. By ensuring proper cleaning, the pipeline operations stay safe and efficient.

1.2 Problem context

This research focuses on the process revolved around cleaning tools at ROSEN Europe B.V. This process starts at planning and ordering parts and marks its end when the tool is ready for shipment. This report, from now on, refers to this process as the cleaning tool fulfillment process. An understanding of the internal processes is necessary to identify root causes and opportunities for improvement.

1.2.1 Background

At ROSEN, cleaning tools are assembled to prepare pipelines for inspection. Cleaning tools consist of a reusable base component, referred to as a tool body, which is adapted with client-specific parts

in the workshop. Each project or client typically has unique specifications based on the pipeline's characteristics and the type of substances it transports, for example, oil or gas. The cleaning tool is sent to the client's location and run multiple times through the pipeline to remove contaminants such as debris or residues. Only after the pipeline is sufficiently cleaned, the inspection phase can begin.

Cleaning tool bodies are generally used for more than one project. After being returned from a completed project, a tool body is first assessed for reusability and then adjusted with new parts to meet the specifications of the next client. The modifications take place in the workshop at ROSEN.

1.2.2 Action problem

During the cleaning tool fulfillment process, inefficiencies and issues often occur. Most importantly, assembly tasks can often not be completed without experiencing any complications.

Although external deadlines for delivery to clients are usually met, these issues result in internal production delays. These delays affect employee efficiency and increase operational complexity.

The action problem is defined as

“Weekly, 36% of cleaning tool orders are delivered with an internal delay.”

Within the ROSEN shop, the guideline is to accept 10 tools per week. To clarify this number, we calculate the number of tools that, on an average weekly basis, are delivered with an internal delay. This means 36% of 10 tools per week, which are 3.6 tools per week that are delivered with an internal delay. The number of tools prepared in the shop occasionally deviate to 15 tools per week, which is considered exceptional.

This figure results from an initial data analysis based on internal data logs covering a period of 81 weeks, from 19/01/2024 to 11/08/2025.

1.2.3 Core problem

Many internal delays can not be linked to specific causes, making it hard to form and implement targeted improvements. This lack of transparency in the cleaning tool fulfillment process limits effective problem-solving and reduces the reliability of cleaning tool fulfillment planning.

The analysis shows that many internal delays cannot be clearly linked to a specific cause. Because it is often unclear when and why these delays occur, it becomes difficult to take targeted actions to improve the process.

Therefore, the core problem is defined as

“There are excessively unclear causes of the internal delays at ROSEN Europe.”

1.2.4 Gap between norm and reality

The reality is that ROSEN is aware of the unclear causes of the internal delays in the cleaning tool fulfillment process. Completely eliminating the internal delays, however, is not realistic; the goal is to minimize them as much as possible. Factors, like supplier issues or transportation problems, are simply beyond ROSEN's control.

The norm is to gain a better insight into the process and its delays. Furthermore, it aims to determine the causes and mechanisms of these delays to enable their prevention. This research focuses on identifying the root causes in question and proposing potential improvements that add to the objective to reduce internal delays in the cleaning tool fulfillment process.

1.3 Research questions and deliverables

Section 1.3.1 outlines the research questions that guide the structure of this thesis. The research aims to identify and reduce the number of unclear and preventable delays in the assembly process of cleaning tools at ROSEN Europe B.V. This is approached through five structured phases, aligned with the core problem.

1.3.1 Main research question and deliverables

The main research question is defined as

“How can the cleaning tool fulfillment process at ROSEN Europe B.V. be analyzed and improved to reduce preventable internal delays?”

Based on this research question, the intended deliverables are

1. Insight into current cleaning tool fulfillment process

A better insight into the current cleaning tool fulfillment process, including the dependencies between different departments and stakeholders. By understanding the current situation, it becomes clear how tasks are coordinated and where the interactions take place. This can be used to understand the complexity of the process and to identify inefficiencies.

2. Root cause analysis

The root cause analysis is used to identify the underlying factors leading to internal delays in the cleaning tool fulfillment process. Linking the observed delays to a specific cause creates space for targeted solutions. This analysis is the foundation of the recommendations to tackle these root causes, eventually resulting in a decrease of internal delays.

3. Improvements opportunities

Based on the insights into the current process overview and the root cause analysis, we propose improvement opportunities to reduce the preventable internal delays. The improvements aim to improve the overall efficiency, approaching the internal norm of ROSEN Europe B.V.

1.3.2 Sub-research questions

To answer the main research question, multiple sub-research questions are given.

Research question 1: “What is the current situation at ROSEN Europe B.V. regarding the cleaning tool fulfillment process, and which stakeholders are involved?”

Research question 2: “Which theoretical models and best practices can be used to analyze the cleaning tool fulfillment process at ROSEN Europe B.V., so that root causes for internal delays can be determined?”

Research question 3: “How is the cleaning tool fulfillment process at ROSEN Europe B.V. structured, and what are the dependencies between stakeholders?”

Research question 4: “What are the root causes of the main problems of the cleaning tool fulfillment process, causing preventable internal delays?”

Research question 5: “How can the identified root causes of internal delays in the cleaning tool fulfillment process be addressed through targeted improvement opportunities?”

1.4 Research design

To help identify the process and propose improvements, Dumas et al. (2018) introduce the Business Process Management Lifecycle, illustrated in Figure 1. This lifecycle includes six stages: process identification, process discovery, process analysis, process redesign, process implementation, and process monitoring. These stages help to be able to give improvements that are based on thorough analysis and can be implemented into the organization. Within this lifecycle, process modeling, as Section 3.1 discusses, and root cause analysis, as Section 3.2 explains, form the basis for change, while the later stages focus on translating insights into improvements and ongoing monitoring. This cycle provides a useful tool for structuring the improvement steps in the cleaning tool fulfillment process.

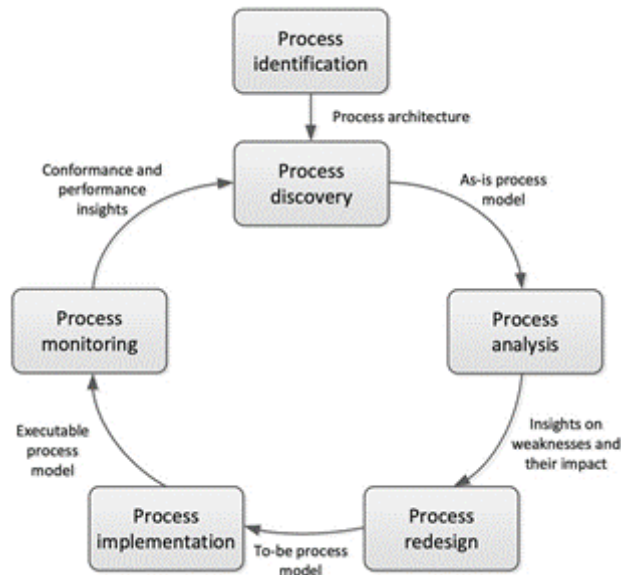


Figure 1: BPM cycle (Dumas et al., 2018)

1.4.1 Research outline

This section defines the research focus and final objective of this report by outlining the content and purpose of each chapter.

To begin with, Chapter 2 introduces the current situation at ROSEN Europe B.V. A flowchart based on company input visualizes the cleaning tool fulfillment process. Additionally, this chapter outlines relevant dependencies and stakeholder involvement. This insight forms the foundation for further analysis.

Building on this, Chapter 3 presents the theoretical background. It discusses relevant theories and literature on Business Process Modelling, with a focus on Business Process Modeling and Notation (BPMN). In addition, several root cause analysis methods are introduced. Together, these provide the theoretical framework that supports both the visualization of the current fulfillment process and the identification of underlying causes of delay.

Next, Chapter 4 translates the current state process into a detailed model using BPMN. This structured representation highlights the dependencies between steps and stakeholders while also making visible where delays most often occur and what factors contribute to them. As such, the model serves as a tool for both analysis and communication with stakeholders.

Following the process analysis, Chapter 5 identifies root causes of delays. This step combines insights from the theoretical framework, the BPMN model, and the root cause analysis.

Based on these results, Chapter 6 formulates the improvement opportunities. These proposals aim to reduce the number of preventable internal delays in the cleaning tool fulfillment process and enhancing overall efficiency.

Finally, Chapter 7 concludes the research by summarizing the most important findings, giving recommendations, and proposing ideas for further research.

2. Current situation

This chapter discusses the current situation of ROSEN Europe B.V., together with the cleaning tools used within ROSEN and all stakeholders involved in the cleaning tool fulfillment process. The aim is to answer the question, “*What is the current situation at ROSEN Europe B.V. regarding the cleaning tool fulfillment process, and which stakeholders are involved?*” First, Section 2.1 covers all the tools ROSEN is working with. Following, Section 2.2 explains the overall cleaning tool fulfillment process. Finally, Section 2.3 explains all the stakeholders involved in this process.

2.1 Tools

This section explains the different tools ROSEN is assembling cleaning, gauging, and In-Line Inspection (ILI) tools. A client has the option to choose between these three different kinds of tools. Typically, the process starts with a gauging tool, followed by a cleaning tool, and concludes with the ILI running through the pipeline. Every client, however, has different wishes, which results in projects that consist of different numbers and kinds of tools. In this research, we are only analyzing the cleaning process, which consists of the cleaning and gauging tools.

2.1.1 Gauging tools

Gauging tools are the first type of tool used during pipeline maintenance and inspection preparations. They are mainly used before a cleaning run and serve as a physical test of the pipeline’s internal geometry. When an inspection has already been conducted, in some cases a gauging-cleaning combination setup is used. This setup is used to conduct a final check to ensure safety. The main goal of the gauging tool is to detect deformations, dents, or bore restrictions that could block or damage the tools used later. Gauging tools are equipped with an aluminum “gauge plate” that is designed to slightly deform if it encounters a restriction that is narrower than expected. If the plate comes back damaged, this indicates that a smaller diameter or other attachments may be needed for the other tools. Gauging tools act as a safety check to verify that the pipeline is physically ready for cleaning and inspection and that the tools will be able to pass through without getting stuck.

2.1.2 Cleaning tools

A cleaning tool’s main purpose is to remove any dirt and buildup that has accumulated inside the pipeline over time. These tools are custom assembled for each project based on factors such as pipeline diameter, material, and transport substance, for example, oil or gas. A cleaning tool is typically run multiple times through the pipeline in what are called “cleaning runs,” gradually improving cleanliness until the pipeline is ready for inspection. Proper cleaning is crucial because leftover debris can interfere with the functioning and accuracy of more sensitive tools used in later stages, such as inspection tools. Cleaning tools are built on reusable tool bodies that are equipped with various brushes, discs, or other mechanical cleaning components that are adapted per project. To trace a cleaning tool back, data is implemented into a so-called ‘transmitter.’

Cleaning tools can be categorized into 2 kinds of tools: normal and heavy-duty cleaning tools. Normal tools often have a standard set of parts attached to them, and additional parts differ per client. These tools are easier and faster to assemble. The parts attached to heavy-duty cleaning tools do not occur very often. Resulting in the need to almost always order them from the supplier, which means a longer lead time.

2.1.3 ILI tools

ILI tools are the most advanced type of pipeline tool used at ROSEN. They consist of high-tech sensors and data recording systems that inspect the pipeline from the inside. These tools are able to detect certain features, such as corrosion or cracks in the pipeline. ILI tools can only do their job correctly if the pipeline has been properly cleaned and cleared. Therefore, they are only used after the cleaning and gauging phases have been conducted carefully and confirmed that the pipeline is ready for inspection.

2.2 Cleaning tool fulfillment process

At ROSEN Europe, the cleaning tool fulfillment process starts once the customer has confirmed the tool selection and the agreement has been finalized with the Sales department. Within ROSEN, such as agreement is referred to as a project, which may include one or more tools. Every tool is composed of multiple parts that together meet the client's requirements. Each part is assigned unique identification code, known as a SAP number, which is used for tracking and procurement purposes.

The first step of the fulfillment process is the planning and coordination phase. In this phase, the client's overall requirements are translated into a detailed plan and technical design. Internal alignment takes place to clarify expectations, verify and complete the available pipeline data, and assess any specific conditions related to the client's infrastructure. The aim of this phase is to ensure a clear and complete project scope before the preparation of the tool begins.

Once the general schedule is made, the preparation of the specific tool can begin. This phase starts with selecting the appropriate tool body and defining its configuration. This configuration is based on a combination of client input and pipeline data to ensure that the tool is suitable for the conditions it will face. An essential document created during this step is the Tool Preparation Sheet (TPS), which outlines the complete set of technical specifications required for the tool. The TPS serves as the foundation for all the remaining activities in the preparation process. With the TPS finalized, the next step is to initiate the flow of materials. A check is done to see which components that are needed for the configuration are already in stock and which must be ordered. Based on this check, a request is made to the Supply Chain department to either retrieve the required parts

from internal inventory or to purchase them from the external supplier, ROSEN Lingen. In some cases, components or even complete tool bodies may be exchanged between ROSEN locations worldwide to ensure availability and meet tight project timelines. Lead times and current stock levels are carefully considered to ensure that all parts will arrive on time.

During the ordering phase, the project timeline is regularly updated to match the expected delivery dates of all tools. This helps to ensure the accurate planning for the assembly phase. The schedule is continuously updated based on, for example unexpected delays.

The assembly phase consists of tasks that are divided and scheduled, and technicians who begin to physically assemble the cleaning tool based on the TPS. This stage requires accuracy, as deviations from the specifications given on the TPS can impact the performance of the tool in the pipeline. The assembled tool is then undergoing the “final test.”

Finally, after the tool passes the final test, it can be prepared for shipment. This marks the completion of the preparation process. The tool is then shipped to the survey site where it will be used for pipeline cleaning and so is handed over to the operational phase.

Figure 2 provides a flowchart of the process described in this section to get a better visualization of the cleaning tool fulfillment process.

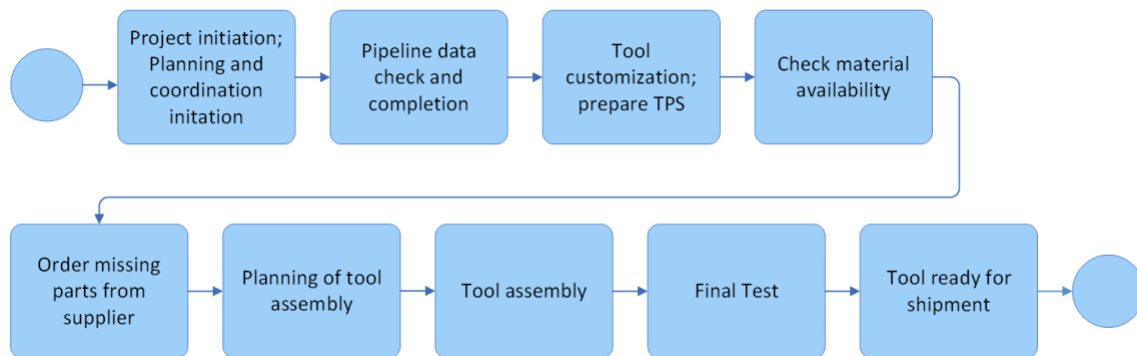


Figure 2: Simple flowchart of the cleaning tool fulfillment process

2.3 Stakeholders

This section further explains the key stakeholders involved in the cleaning tool fulfillment process at ROSEN. These functions are divided into the project management team and supporting roles. Section 2.3.1 discusses the project team, and Section 2.3.2 discusses the other stakeholders.

2.3.1 Project management team

A project management team consists of the Project Manager, Survey Lead, Tool Lead, Dat Lead, and the Schedule Lead. Every project team meets once a week to discuss the progress of the project they are working on. Each Project Manager and Tool Lead is responsible for specific regions and countries. This makes the distribution of projects much clearer, returning projects can be handled more efficiently, and cultural differences are known so they can be taken into account while handling a project. Next to the Project Manager and Tool Lead, project management teams and employees linked to a project can vary, while for returning clients, frequently the same team is chosen, when possible. We do not discuss Dat Lead, as this Lead only is working with data from the ILI tools and so is outside this research's scope.

Project Manager

The Project Manager (PM) at ROSEN Europe is not only responsible for a project from its start to finish but more importantly for its successful completion. So, the PM oversees all phases of the project. The PM also serves as the main contact person for both internal and external stakeholders. This ensures clear communication throughout a project. A final responsibility of the PM is to make sure that all "Leads" receive the right information at the right time.

Survey Lead

The Survey Lead is, in this scope, mostly responsible for verifying the completeness of the pipeline data, which is essential for successful order fulfillment. If any data is missing or incomplete, the Survey Lead must gather the information from the client. Additionally, the Survey Lead is responsible for all activities from the moment the tool is shipped to the customer until the job is completed and the tool is returned to ROSEN, which is outside this research scope.

Tool Lead

The Tool Lead (TL) is responsible for planning and managing all activities within the workshop. The role of the TL already begins after the handover from sales to the PM and continues until the cleaning tool is fully assembled and is ready for shipment. The TL is held accountable for the assembly process and ensures that the tool can be delivered in time by communicating with the Shop Operations (SOP) Coordinator.

Schedule Lead

The Schedule Lead (SL) is responsible for creating the overall schedule of a project. This involves planning in different phases, starting with an initial relatively broad schedule, which is later detailed further by the Workgroup Lead. The project is divided into five different stages: preparation, mobilization, survey, rundate, and reconditioning. The SL oversees whether tasks are completed on time to ensure the planning remains up to date. The SL manages task statuses such as request, proposal, and completion to monitor and meet project milestones.

2.3.2 Other stakeholders

Other people also play crucial roles in successfully completing a project. In addition to the PMs and TLs, each country or region is typically assigned specific Tool Customizers and a Shop Operations Coordinator. This structure enables projects to be handled more efficiently, as personnel develop specialized knowledge and experience within their designated regions, especially for returning clients. However, staffing availability and regional demand can vary over time. In such cases, responsibilities may be reassigned, allowing personnel to support projects originating from regions other than their usual area of responsibility.

Tool Customizer

The Tool Customizer (TC) is responsible for “customizing” the tool. This means a TC engineers the tool setup, based on the object data and run conditions. The TC “customizes” the Tool Preparation Sheet (TPS), which is a document that details all requirements for the specific tool.

Shop Operations Coordinator

The Shop Operations Coordinator (SOP Coordinator) is primarily responsible for ordering the parts required to meet the client-specific tool specifications. The SOP Coordinators check which parts are needed based on the TPS and will make an order to the Supply Chain department.

Supply Chain department

The Supply Chain (SC) department receives the order from the SOP Coordinator. The SC department has direct contact with ROSEN’s warehouse employees and their supplier, ROSEN Lingen. SC department employees decide which parts can be supplied by the warehouse and which need to be ordered from the supplier. They consider lead times, inventory levels, and additional relevant factors in their decision-making process.

Workgroup Lead

The Workgroup Lead (WL) oversees the shop floor planning, based on available capacity, assigning certain tasks to technicians in alignment with the overall project planning.

Mechanic Technician

Finally, the Mechanic Technicians (MT) come into the process. An MT ensures that the assembled tool matches the order specifications and the design shown on the TPS.

Final Test Technician

The Final Test Technician (FT) is responsible for comparing the assembled tool with the TPS and set requirements to be able to release the tool for shipment.

Figure 3 illustrates the order and overlap of functions involved during project execution. It shows which roles are active in the project execution phase, beginning with the Schedule Lead and

continuing through to the Mechanic Technician. The figure also highlights that certain functions, such as the Project Manager, Tool Lead and Schedule Lead, remain engaged across multiple phases. While the diagram represents the standard sequence, in practice the process may vary when issues arise, additional information is required, or deviations from the standard procedures occur.

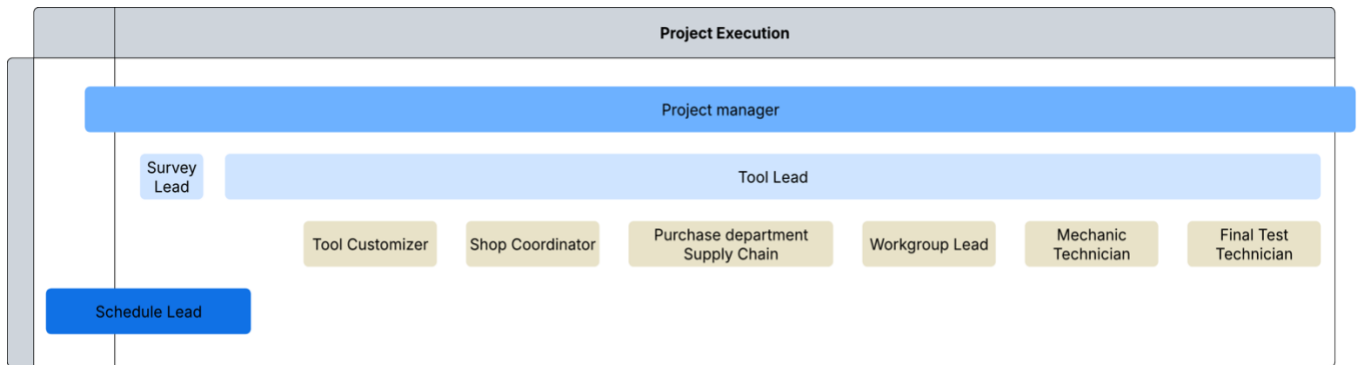


Figure 3: Order and overlap of functions

3. Literature review

This chapter covers relevant theories to answer the question, “Which *theoretical models and best practices can be used to analyze the cleaning tool fulfillment process at ROSEN Europe B.V., so that root causes for internal delays can be determined?*” In Section 3.1 the focus lies on process modeling to gain transparency into the cleaning tool fulfillment process and identify potential bottlenecks. Section 3.2 highlights different root cause analysis methods that support the identification of underlying causes of internal delays.

3.1 Business Process Management

Business Process Management in its core is a clear representation of business processes, including the tasks that are performed and the restrictions that apply during their execution (Weske, 2012). The most important goal of business process management is achieving a better understanding of a company’s operations and the relationships between them (Dumas et al., 2018; Weske, 2012).

3.1.1 Business Process Modeling (BPM)

Business Process Modeling (BPM) is a core element of the Business Process Management lifecycle, as Section 1.4 illustrates (Dumas et al., 2018). Business process models, which represent these operations, are characterized by three main properties: mapping, abstraction, and purpose. A model represents a real-world process but only focuses on the most relevant elements and leaving out certain unnecessary details (Dumas et al., 2018). Its purpose is to determine which aspect of the real-world process is highlighted or can be excluded (Dumas et al., 2018). There are a few important reasons why creating business process models can make a big difference for a business.

Ensuring communication and understanding

Explicit business process models, particularly when expressed using a graphical notation, serve as common communication instruments for stakeholders (Weske, 2012). This enables different parties, ranging from operational managers to process participants, to communicate efficiently, refine processes, and resolve any possible misunderstandings or unclear points (Weske, 2012). Diagrams are often favored over textual descriptions, as these can be difficult and inefficient to read and prone to misinterpretation (Dumas et al., 2018).

Enabling analysis and improvement

After the processes are modeled, they can be analyzed (Weske, 2012). By using these process models as a starting point, process improvement can be developed (Weske, 2012). A clear understanding of the process achieved through modeling is essential, because it forms the basis for later steps like process analysis, redesign, or automation (Dumas et al., 2018).

Supporting organizational design

Models created for organizational design are mostly abstract (Dumas et al., 2018). They are built to create a shared understanding during the discovery phase of the BPM lifecycle and are used as

a basis for later redesign activities (Dumas et al., 2018). These models must remain intuitive enough to be easily comprehended by various stakeholders (Dumas et al., 2018).

3.1.2 Business Process Model and Notation (BPMN)



Of all the various modeling languages, Business Process Model and Notation (BPMN) is the most widely used approach (Chinosi & Trombetta, 2011). BPMN serves as a standardized notation for representing business processes. It is derived from principles of traditional flowcharting (Von Rosing et al., 2015).

The primary purpose of BPMN aligns with that of the Unified Modeling Language (UML) in the domain of object-oriented design: to identify and combine the best practices of existing approaches into a new, widely accepted, and standardized language (Weske, 2012). BPMN combines the best practices developed from the business modeling community and builds on earlier modeling techniques like UML activity diagrams and Event-driven Process Chains (EPCs) (Weske, 2012; Recker, 2010).

BPMN is widely used because its main goal is to offer a clear and easy-to-understand way for all stakeholders, both business and technical business users, to communicate (Weske, 2012; Von Rosing et al., 2015). BPMN serves as a common language, thereby bridging the communication gap that frequently occurs between the conceptual phase of business process design and the technical phase of process implementation (Weske, 2012; Von Rosing et al., 2015). It was introduced to combine the benefits of a simple, convenient notation with a clear and unambiguous interpretation (Weske, 2012). BPMN’s strength lies in its ability to visually represent processes in a clear and detailed manner. Its standardized format also enables advanced analysis and simulation in later stages of process improvement (Dumas et al., 2018).

BPMN uses different kinds of elements like tasks, symbols, gateways, events, swimlanes, connecting objects, and data objects. These elements help to clearly show how the process goes from one step to the next. The following tables present the symbols of the different elements, the type of element, and the explanation of the elements.

Tasks

Symbol	Type	Description
	Plain task	A normal task without a special purpose or defined category. It represents a basic activity within the process.
	Send or receive task	The task is linked to a message. The black box means sending information or a message to another participant to start or continue communication. The white

		box means a task that waits for information or a message to arrive from another participant before the process can continue.
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Table 1: BPMN symbols (Von Rosing, 2015)

Gateways



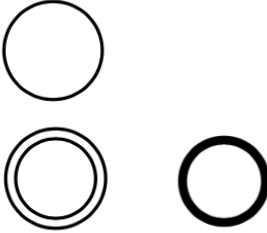

Symbol	Type	Description
	Exclusive gateway (XOR)	Used when several conditions are mutually exclusive and only one decision is possible, for example, “yes” or “no.”
	Parallel gateway (AND)	Activate all outgoing branches simultaneously. The merging parallel gateway waits for all incoming branches to be completed before continuing the sequence flow.

Table 2: BPMN gateway symbols

Events

Symbol	Type	Description
	Start, intermediate or end	Used as a general event: the start, intermediate, or end of a process. A thin circle represents a start event, double lines represent an intermediate (throwing) event, and a thick line represents an end event.
	Message	<p>Symbolizes interactions with external entities. A thin circle represents a start event, double lines represent an intermediate (throwing or catching) event, and a thick line represents an end event.</p> <p>A black symbol represents outgoing, and white represents</p>

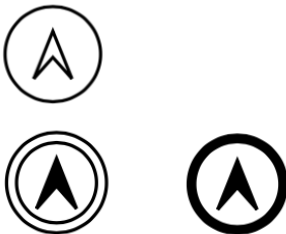
		incoming.
	Escalation	Escalating to a higher level of responsibility. A thin circle represents a start event, double lines represent an intermediate (throwing or catching) event, and a thick line represents an end event.

Table 3: BPMN event symbols

Swimlanes


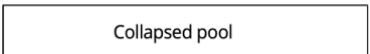
Symbol	Type	Description
	Pools and lanes	Represent responsibilities for activities in a process. Pools represent whole organizational units, and lanes subdivide pools or other lanes hierarchically.
	Collapsed pool	Represents an external organization.

Table 4: BPMN swimlanes symbols

Connecting objects


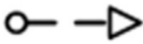

Symbol	Type	Description
	Sequence flow	Sequence flows connect events, gateways, tasks, and subtasks.
	Message flow	Represent communication and interactions between pools.
	Association	Combine data objects and artifacts with other elements.

Table 5: BPMN connecting object symbols

Data

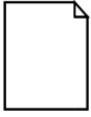

Symbol	Type	Description
	Data object	Represents information flowing through the process; input and output to the activities of a process.
	Data store	A place where the process can read or write data, for example, a database or a filing cabinet. It persists beyond the lifetime of the process instance.

Table 6: BPMN data symbols

3.2 Root cause analysis methods

This section presents the concepts and methods of Root Cause Analysis, essential for understanding how problems in organizations can be identified and analyzed.

3.2.1 Root Cause Analysis

Beneath every problem that a company faces lies an underlying cause, and effective problem-solving requires identifying and eliminating this cause rather than just addressing its symptoms. It enables organizations to develop solutions that prevent the recurrence of problems (Doggett, 2005). This systematic approach is known as Root Cause Analysis (RCA) (Pietsch et al., 2024). While Business Process Modeling (BPM) helps to visualize where delays and problems occur in a process, Root Cause Analysis (RCA) seeks to answer why they occur. It serves as a structured method to identify the fundamental causes within a process (Pietsch et al., 2024). Eliminating these issues is of critical importance in any operating environment (Doggett, 2005).

RCA is widely utilized in sectors such as manufacturing to determine the causes of repeating issues, and thereby improving efficiency (Pietsch et al., 2024). Effective RCA relies on the integrity of the selected root cause, as a trustworthy root cause leads to a clear managerial decision for action (Doggett, 2005). RCA methods must also possess important performance characteristics such as the ability to find root causes, identify relationships, categorize causes, promote focus, stimulate discussion, and allow for the evaluation of findings (Doggett, 2005). The goal of this analysis is not to assign blame to individuals, but rather to focus on the organizational setting and the systems involved in the error (Percarpio et al., 2008).

RCA is better understood as a collective term for a wide range of tools and techniques. These tools vary in structure and application, from highly systematic approaches to more creative, open-ended

ones, and must be selected depending on the specific problem at hand (Andersen & fagerhaug, 2006). Two popular and straightforward tools utilized in these knowledge-driven approaches are the Fishbone Diagram and Five Why technique. These methods are often applied in combination to identify the root cause of a problem (Kumah et al., 2024).

3.2.2 The Five Whys Technique

The Five Whys technique was developed within the Toyota Production System as a technique to progressively investigate the causes of problems (Ohno, 1988). By repeatedly asking the question “why?”, the researcher digs deeper into uncovering the underlying cause of a problem. Although the number five is not fixed, the principle is to continue asking until an underlying explanation is reached that can be addressed with targeted solutions (Serrat, 2017). The Five Whys technique is considered a basic yet powerful tool that is foundational to RCA and essential for robust problem-solving in industry (Barsalou & Starzyńska, 2023). The core objective of this approach is to look beyond the most obvious or noticeable causes, which are often only symptoms of the failure, in order to find the underlying cause. With the underlying explanation that, if corrected or prevented, it ensures that the failure cannot recur (Barsalou & Starzyńska, 2023).

For an effective application the technique is highly beneficial for uncovering specific system and human factors contributing to a problem (Gangidi, 2018). The validity of the resulting causal chain can be verified by reversing logic and confirming that each step makes clear sense using the term “therefore” (Gangidi, 2018). Furthermore, implementing Five Whys as a collaborative team activity, involving personnel such as operators and managers, often leads to improved investigation results (Serrat, 2017).

3.2.3 The Fishbone Diagram

The Fishbone Diagram, also referred to as the Ishikawa or cause-and-effect diagram, was originally developed to visualize an RCA and generate ideas for feasible improvements (Tagaram & Chen, 2024; Bose, 2012). The Fishbone diagram is a visual tool that organizes and displays the different factors leading to a specific effect or problem by mapping out their cause-and-effect relationships (Kumah et al., 2024). The structure of the diagram features the main problem to be resolved placed graphically at the “head” of the diagram (Bose, 2012). The larger factors are designated as the main bones, while smaller bones represent the detailed causal factors or sub-causes (Bose, 2012). This visual process results in a comprehensive overview of problem causes, which can help reveal fundamental root causes.

The diagram helps systematically identify multiple potential causes of a problem. The standardized Fishbone Diagram organize the causes into major categories or domains. These major causes can be categorized as methods or systems, machines or equipment, manpower or people, materials, environment, and measurement (Bose, 2012). Organizing potential causes into these fishbone

categories ensures that analysis spans technical, human, procedural, and environmental factors (Tagaram & Chen, 2024). The model, however, is versatile, and some models expand or adapt their categorization, which can lead to a different number and different kinds of categories, depending on the kind of problem (Doggett, 2005). The goal is to establish the link between the problem and the cause, as action cannot be taken until this relationship is understood (Doggett, 2005).

A notable advantage of the Fishbone Diagram is its ease of use and its effectiveness in narrowing the investigation's scope to be more manageable (Doggett, 2005; Kumah et al., 2024). By visually organizing the possible causes, it helps stakeholders build a shared understanding of both the causes and potential solutions (Kumah et al., 2024).

3.2.4 Combining Five Whys Technique and Fishbone Diagram

Using the Five Whys together with the Fishbone Diagram creates a strong and practical way to analyze a process. Each method has its own strengths and focuses on different parts of the root cause analysis. Even though there are many root cause analysis methods, these two are often used together because they help identify the deeper underlying causes in a process (Barsalou & Starzyńska, 2023).

Using both methods together makes the RCA process stronger. The Fishbone Diagram identifies all possible causes, while the Five Whys helps to check and better understand the most important ones. The Fishbone Diagram can finally be used to visualize its findings. This combination fits with Heerkens and Van Winden's (2017) idea that a good analysis should start broad and then focus on the real cause to achieve lasting improvements.

4. Process analysis

This chapter provides an analysis of the process. It answers the question: “*How is the cleaning tool fulfillment process at ROSEN Europe B.V. structured, and what are the dependencies between stakeholders?*” Section 4.1 describes key concepts needed to understand the process. Section 4.2 explains the cleaning tool fulfillment process as-is according to Business Process Mapping and Notation (BPMN).

4.1 Key concepts

The following section explains key concepts involved in ROSEN’s processes, needed to understand these processes. This information gives background information to get a better understanding of the current process and other various activities. Section 4.1.1 states and explains the scheduled and actual dates ROSEN uses, Section 4.1.2 highlights the Tool Preparation Sheet (TPS), and finally Section 4.1.3 provides a detailed explanation of revisions.

4.1.1 Scheduled and actual dates

Within ROSEN a lot of different dates are linked to an order. All these dates have an abbreviation that the company uses for both day-to-day communication and for system use. We list the most important ones.

SDR	The <i>Scheduled Date of Requirement</i> is the date requested by the Project Manager for when the tool must be completed and ready for shipment. It reflects the client’s desired or contractual delivery deadline.
STA	The <i>Start Target Date</i> marks when the Tool Lead confirms that tool execution can start. It is the date when the request is entered into the system, based on the availability of complete pipeline data.
TDA	The <i>Target Date of Availability</i> represents the confirmed scheduled completion date for the tool, set by the Tool Lead. It depends on the availability of both the tool and all required parts. The aim is to align this target date as closely as possible with the client’s requested <i>SDR</i> .
APS	The <i>Actual Process Start</i> is automatically generated by the system once the first working hours are booked for a tool. It confirms the actual moment the process starts in practice, allowing a comparison with the planned <i>STA</i> .
RDA	The <i>Real Date of Availability</i> is automatically set once the tool has been fully completed and released for shipment. It shows the actual finishing date, which can then be compared with the <i>TDA</i> to measure on-time performance.

Table 7: dates used within ROSEN

The most important date is the TDA, as this date is the most used term within ROSEN. The TDA always serves as a guideline, and when certain problems arise, the first step is to check whether the order can still be completed on time according to this date.

4.1.2 Tool Preparation Sheet (TPS)

A Tool Preparation Sheet is essential for the cleaning tool fulfillment process. The sheet contains information about the tool and who is responsible, so the designated Project Manager (PM), Tool Lead (TL) and Tool Customizer (TC). Further, the TPS displays which parts and equipment are needed, the desired design and structure of the tool, and a visualization of the required tool. This way everything is well-defined and clear for the mechanics.

4.1.3 Revisions

In the cleaning tool fulfillment process, a revision refers to any change made to the TPS or related project specifications after the initial version has been released. Revisions are common throughout the process, as cleaning tools are custom-made and often subject to late changes in requirements or corrections of earlier mistakes.

Revisions can arise from different sources. A frequent cause is the client: customers may request changes after the initial scope has been set, for example, by requiring an additional cleaning run or changing the tool specifications. Revisions also occur due to errors or incomplete information in the TPS. In practice, these errors can only become clear during later stages. Finally, revisions can arise in the assembly phase. When problems arise in the workshop, alternatives may need to be found. This means that the TPS needs to be adjusted to match the parts that are either already in stock or can be delivered on time. Another alternative is to find a part that is in stock and that resembles the required part a lot. This, however, is a choice that needs to be made carefully.

Revisions recur a lot, as they can happen at different stages, during customization, ordering, or even assembly. They come in all different forms, as even a small change to a TPS is already stated as a revision. It also can be done when a solution already exists.

4.2 Current cleaning tool fulfillment process

This section provides a detailed overview of the current cleaning tool fulfillment process, serving as the foundation for identifying root causes and improvement opportunities in later sections. This section first explains how the study gathers information about the process, then Section 4.2.1 provides why we chose to use Business Process Modelling and Notation (BPMN), and finally Section 4.2.2 outlines the cleaning tool fulfillment process step by step using BPMN. Each phase describes the roles of different stakeholders and shows how their tasks connect. The goal is to give a clear and complete overview of the process, supported by visual models for clarity.

To establish a correct model of the current situation, first, a meeting with 6 stakeholders was held. By means of input from different viewpoints of these employees and several questions that were asked, we came down to an overall process. To gain more knowledge, we interview relevant stakeholders again to gain more detailed knowledge about the process at ROSEN. These interviews stay open-ended because their purpose is not only to build an overall understanding of the fulfillment process but also to build trust with stakeholders and already get a view of some recurring issues. In this section BPMN is used to model the process as is. The process is divided into different sections.

4.2.1 BPMN choice

As previously stated in Section 3.1, BPMN's strength lies in its ability to visually represent processes in a clear and detailed manner that can be easily understood by both technical and business stakeholders. For ROSEN this is particularly valuable, as the cleaning tool fulfillment process involves multiple stakeholders, ranging from project managers to mechanics. The cleaning tool fulfillment process includes complex scheduling, handovers, and dependencies, making a clear visual presentation useful to understand the process and identify potential inefficiencies. Furthermore, BPMN diagrams can, in a later stage, be used for analysis and simulation, which allows ROSEN to test potential changes and evaluate their impact before implementing them in practice.

4.2.2 BPMN of the cleaning tool fulfillment process

As Section 2.1 highlights, multiple stakeholders are involved in the cleaning tool fulfillment process. This section thoroughly presents all the dependencies and steps in which stakeholders are involved in the cleaning tool fulfillment process and provides an explanation of the process where needed. Because most of the tasks from a certain employee are connected to tasks from other employees, the cleaning tool fulfillment process is visualized in its entirety. To get a better view, the process is divided into different phases. The process starts with the pre-execution phase, followed by the customization phase, then the pre-procurement phase, the procurement phase, and finally the assembly phase. Each phase is connected to each other. The BPMN's visualize the process and make a starting point for later root cause analysis.

Pre-execution phase

Figure 4 illustrates the initial phase of the cleaning tool fulfillment process. The process starts when an order is processed by the Sales department. Operational requirements are established in consultation with the Project Manager (PM). However, systematic consideration of whether the order can be completed within the required timeframe is often limited. A kick-off meeting is frequently conducted under time constraints; particularly cleaning tools are then not a central topic of discussion. A kick-off meeting is normally held to discuss important information and, most importantly, to understand the project scope. This meeting, however, is not always conducted, mostly also due to time constraints. Following this, the Schedule Lead (SL) develops a detailed

schedule and plans the SDA (see Table 1). Once this is completed, the SL initiates task requests, which involve scheduling specific phases of project execution, the preparation phase, for example. During this phase of the project, pipeline data is reviewed multiple times. If data is missing, the first point of contact is the Survey Lead, followed by the client. If data remains incomplete after these communications, assumptions, based on experience and historical data, are made in consultation with the client, accompanied by the development of a risk mitigation plan. For instance, if a tool becomes stuck in the pipeline, liability rests with the client rather than ROSEN. There, however, still are situations where data is missing, or the data is filled in incorrectly.

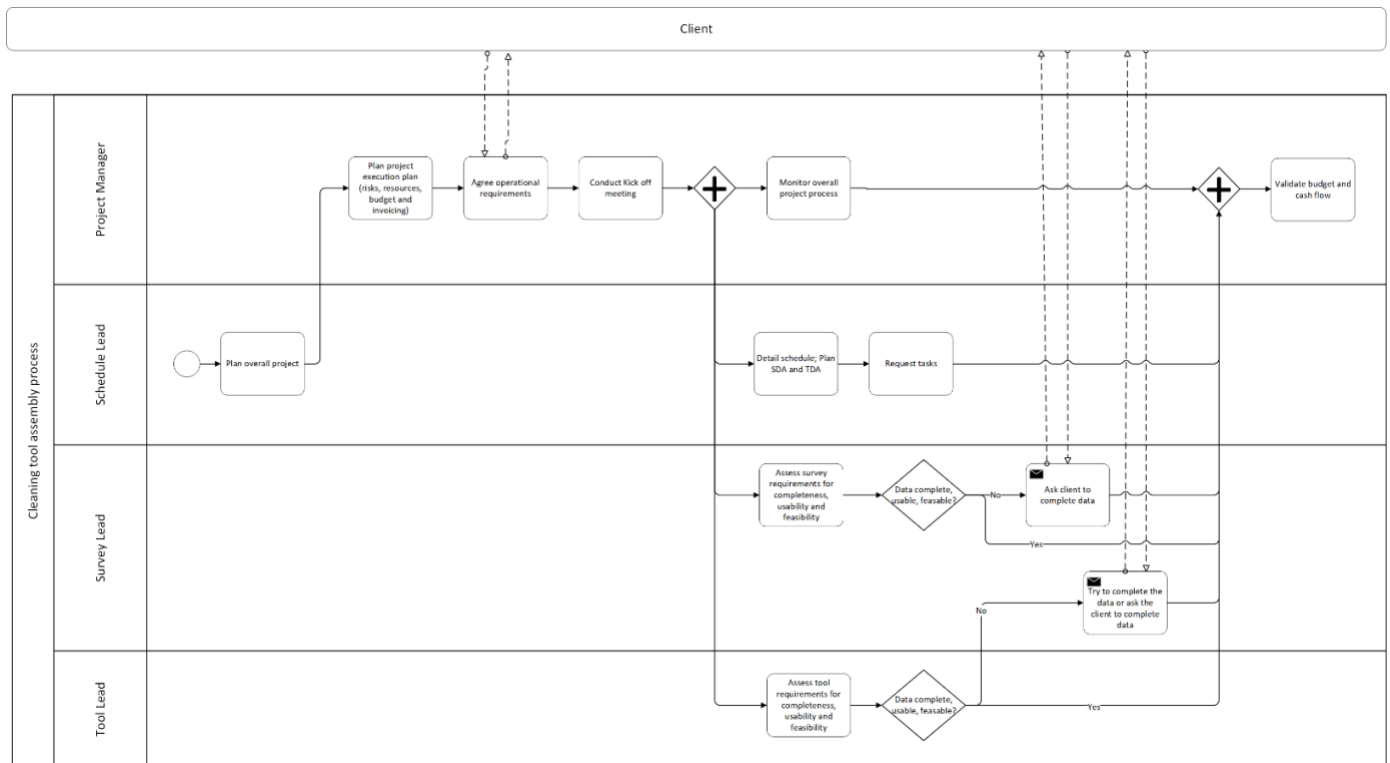


Figure 4: Pre execution phase BPMN

Tool customization phase

Figure 5 presents the subsequent stage of the cleaning assembly process. The “request tasks” step for the Tool Lead (TL) is a follow-up from the “request tasks” of an SL. When the overall phases are requested, tools can be assigned to a Tool Customizer (TC) and to a Shop Operations Coordinator (SOP Coordinator), which varies per project. The primary priority is to allocate personnel to preassigned geographic regions. All orders are categorized into four regions, each overseen by a designated TC. Every SOP Coordinator is responsible for two of these regions. In practice, assignments are often influenced by personnel availability. Next, pipeline data is once again reviewed by multiple employees, often necessitating follow-up questions and rework. Once all relevant data is confirmed, the appropriate configuration can be determined. This configuration is crucial as this makes sure the tool is suitable for the conditions it will encounter in the pipeline. When no similar configuration of a tool that already has been customized exists, a new

configuration request is sent to the Lingen facility. Following confirmation, the Tool Preparation Sheet (TPS) is created, stored in a shared folder, and distributed via email to all stakeholders. Email is the preferred communication channel, as it is accessed more frequently than folders on someone's computer.

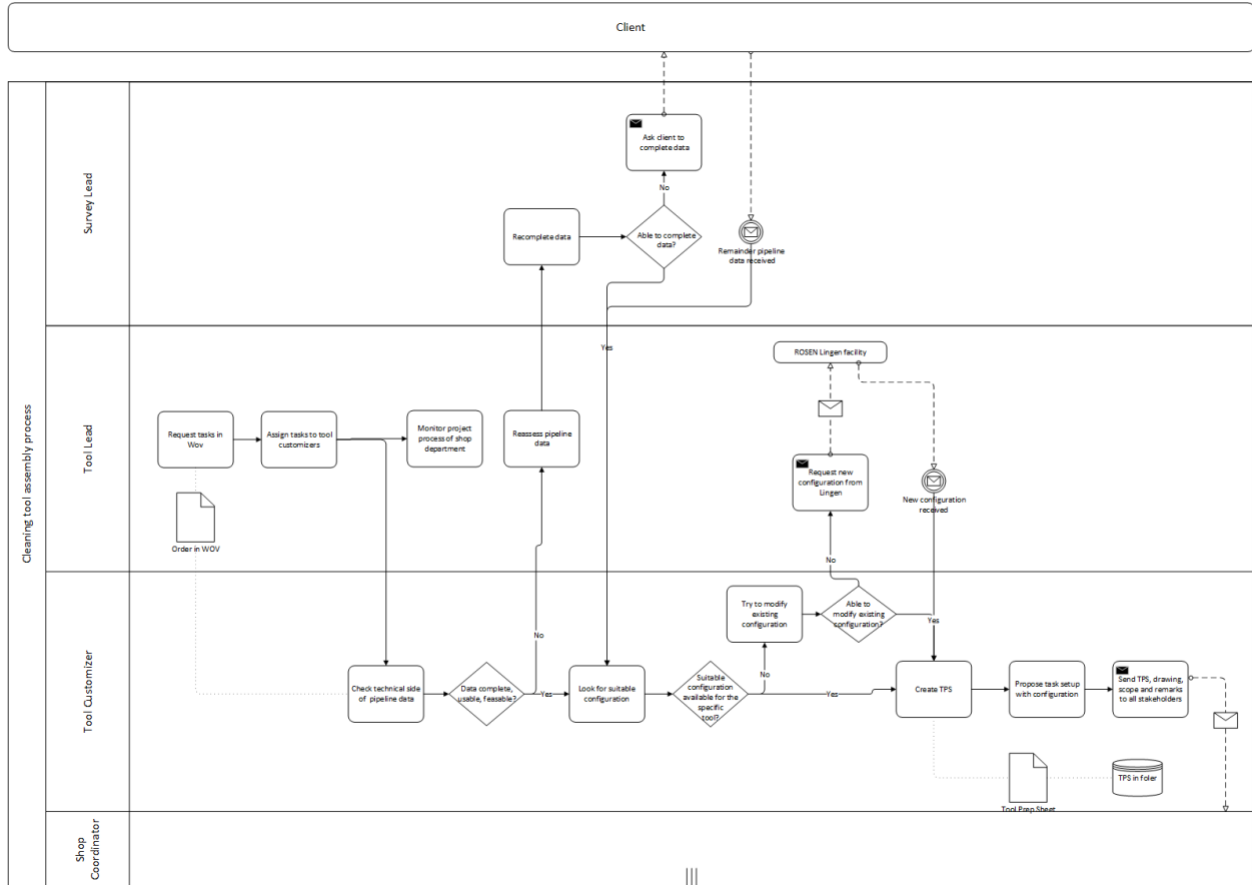


Figure 5: Tool customization phase

Pre-procurement phase

Figure 6 depicts the start of the procurement process. Once the TPS has been completed and communicated to all relevant stakeholders, SOP Coordinators begin their activities. It is possible that a required tool body is not available at the Oldenzaal facility. In such cases, other ROSEN locations are asked to check whether the necessary tool is available in inventory. If the required tool body is unavailable at other facilities, the matter is escalated to a higher decision-making level. On the contrary, if availability at another location is confirmed, responsibility for further processing transfers to the Supply Chain data department. They verify internal inventory and place supplier orders when necessary, at the Lingen facility. When the body needed is available at the Oldenzaal facility, then SOP Coordinators determine which parts still need to be ordered, and which are not. Then, the assessment of delivery times is done to avoid late arrivals. If it is determined that parts cannot be delivered in time to meet the TDA, the SOP Coordinator informs the relevant TL. When alternative sourcing from other ROSEN facilities is unsuccessful, the TL concludes that meeting the TDA is not feasible. The order now will be escalated to a higher

management level. At this level, strategic decisions may be made, such as negotiating with the supplier to reprioritize orders for high-value or strategically significant projects.

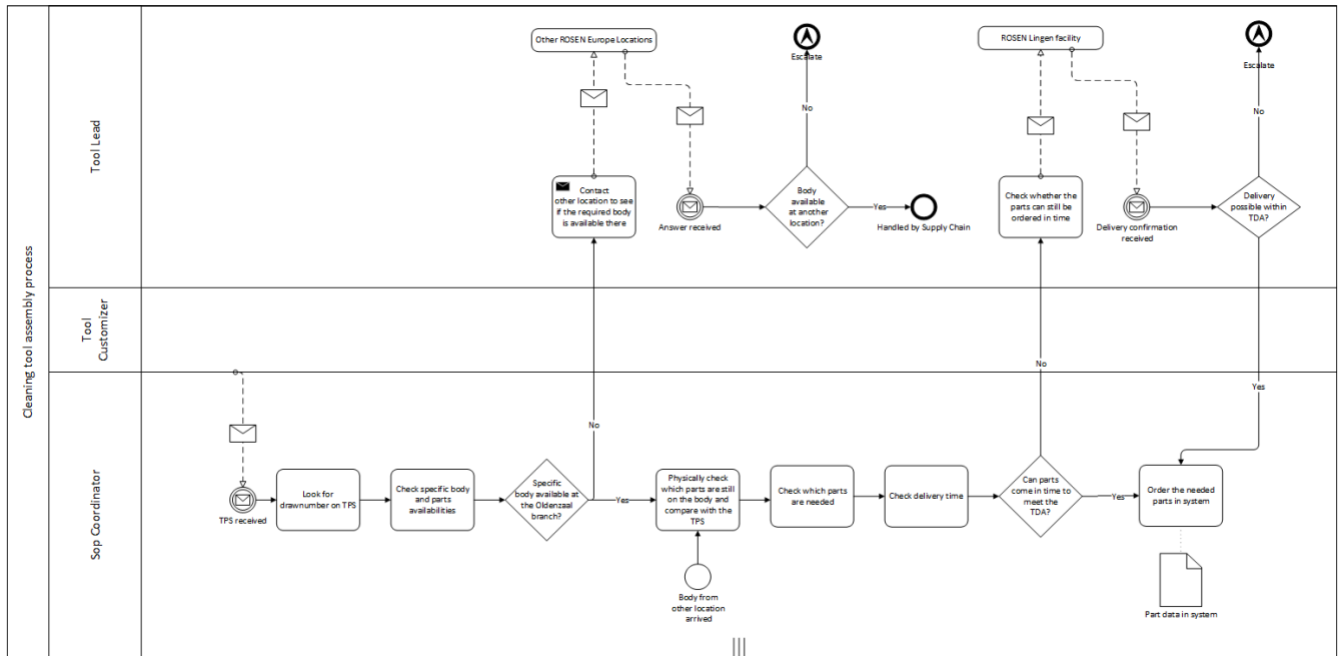


Figure 6: Pre-procurement phase

Procurement phase

Figure 7 visualizes the procurement process. The required parts put in the system by the SOP coordinator are checked. They are first compared to the internal inventory of ROSEN, and then the still needed parts are ordered by the Supply Chain department at the supplier. Based on the Tools that are needed to be done, so based on the TDA, the Workgroup Lead develops a weekly schedule for cleaning tool assembly, organizing tasks in batches rather than at a detailed, tool-specific level.

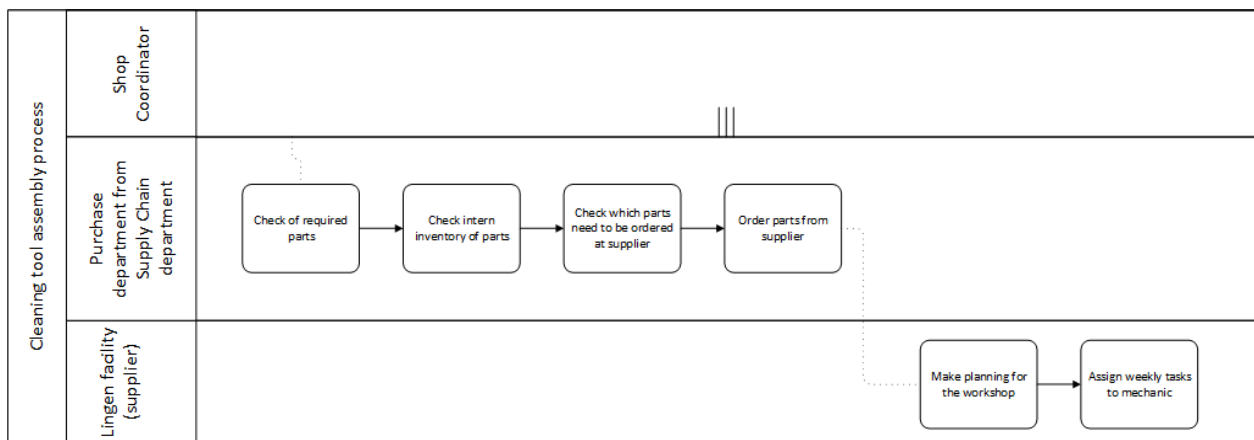


Figure 7: Procurement phase

Tool preparation phase

Figure 8 focuses on the preparation and the assembly of the tools within the workshop. In the next step, the Mechanic Technician (MT) scans the planning in the system. Chooses, normally, the one planned first; he gets the printed TPS and compares whether the information on the TPS matches with the information in the system. When it does not match, the MT goes to the TC for the information to be adjusted. After the information is correct, the matching box number gets requested. This means that all the associated parts needed to assemble the tool are requested to go to the “box” of the MT working on the tool.

During this process, the delivery time of certain parts needed can be delayed coming from the supplier. In this situation, a “change order” is requested in the system. Which means that the assembly needs to be rescheduled, and a possible later TDA is requested. The weekly planning now requires to be updated. The new planning is communicated to the MT.

After the box number is requested for a certain tool, all necessities are checked by the inventory specialist. It happens that in this stage, some parts are not in stock yet. Then again, a “change order” is needed and requested in the system. This can go on as a loop, as the MT may choose to work on the next tool. This tool, however, can also miss some needed parts. Change orders can be repetitive, with the same tool undergoing multiple, sometimes three or four, change requests. The change orders go in both ways; the TDA can be requested to change back or forward. Forward, when, as explained, parts are not available in time as communicated by the supplier or due to another problem, and backward, when an MT chooses to work on a tool earlier than planned. Upon completion and verification of assembly, the tool is prepared for shipment, marking the conclusion of the cleaning tool fulfillment process.

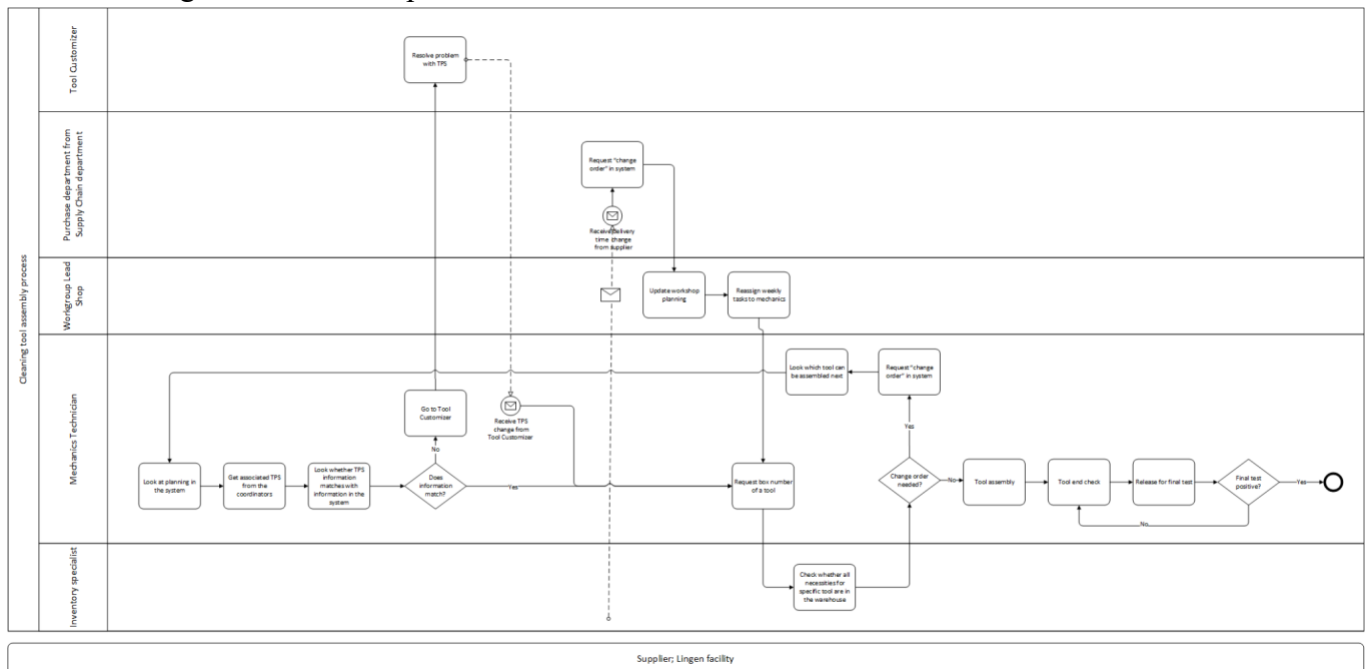


Figure 8: Tool preparation phase

5. Root cause analysis

This chapter answers the sub-research question: “*What are the root causes of the main problems of the cleaning tool fulfillment process, causing preventable internal delays?*” To identify and understand these problems, the research follows a structured and stepwise root cause analysis. This ensures that the findings are based on systematic reasoning rather than only observations. Figure 9 visualizes the sequence of steps and their input and output of the root cause analysis below.

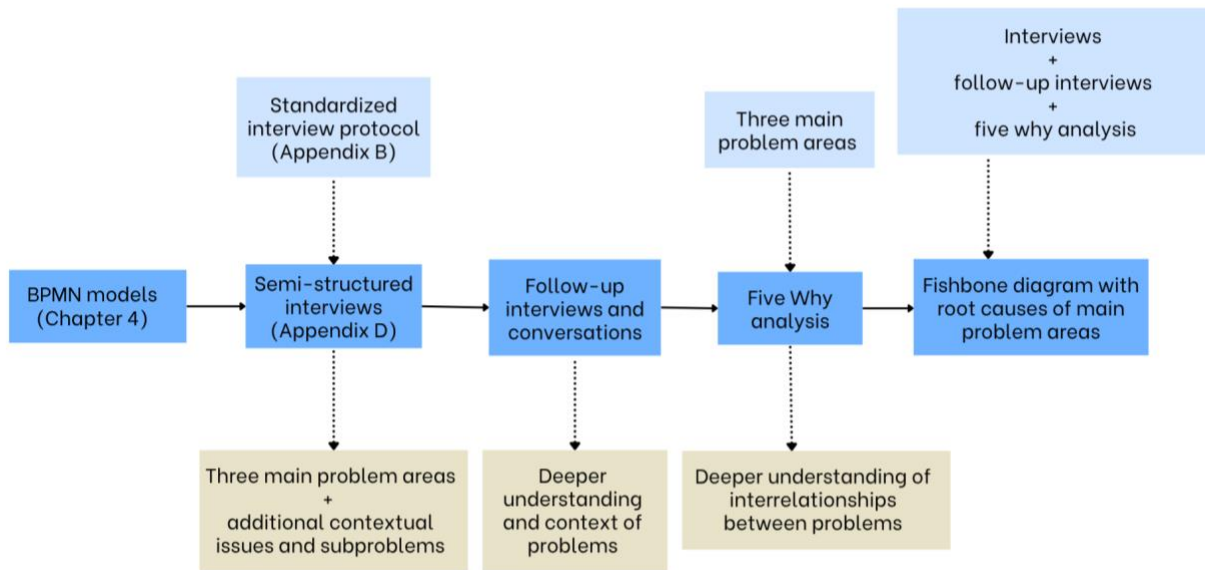


Figure 9: Flowchart root cause analysis

Each step builds on the previous one. Section 5.1 describes the approach of the semi-structured interviews and presents the three main problems. Section 5.2 deepens the understanding through a Five Whys analysis. Finally, Section 5.3 integrates all findings into a final Fishbone Diagram that forms the basis for Chapter 6. This stepwise approach connects the theoretical background from Chapter 3 with the process model from Chapter 4 and ensures a logical transition from identifying issues to developing improvement.

5.1 Semi-structured interviews

The root cause analysis builds on the process understanding developed in Chapter 4. The BPMN models not only provide a detailed overview of how activities are connected but also already provide an understanding of some problems that arise in the process. Based on this knowledge, we conduct semi-structured interviews with seven stakeholders from six different departments directly involved in the cleaning tool fulfillment process (Appendix B). The interview protocol follows a standardized set of questions (Appendix A) to ensure consistency and comparability of responses while still leaving room for follow-up questions based on the respondents' answers. The purpose of this step is to set the main problem areas, uncover additional issues, and collect perspectives from different points of view on potential causes. Standardization ensures that key topics such as

complications and recurring challenges can be discussed consistently, while flexibility still allows to gain unexpected insights. One of the main strengths of the semi-structured interview method is its interactivens, which enables the interviewer to adapt questions based on participants' responses and encourages open, in-depth communication, leading to richer and more meaningful data, while keeping structure (Kallio et al., 2016).

The semi-structured interviews identify the three main problem areas, as these most often emerge from stakeholders. Additionally, the other problems seem to almost all point to these main problems. Therefore, we establish the following problem areas as the most significant and impactful:

1. Parts not available in time
2. Incorrect parts delivered
3. Unable to execute tasks efficiently in the workshop

After the interview analysis, we use a Fishbone Diagram, to structure the problems we identify (Appendix C). Instead of only having an unstructured list of issues, the diagram helps to visualize the problems and to consider all standard aspects. The results of the interview analysis, also form the input for more follow-up interviews. As these are needed to get a better understanding and to be able to connect the causes to the main problem areas.

5.2 Five Why analysis

To reach an even deeper understanding of what the root causes of the main problem areas are and possibly find out even more causes through input from stakeholders, we use a Five Why analysis, as Section 3.2.2 describes. This method helps to identify underlying causes by asking “why” several times for each main problem area until the root cause becomes clear. The most significant advantage of the Five Why analysis is that it is systematic: it forces participants to go step by step, thereby reducing the risk of jumping to conclusions. The other advantage is that it is action-oriented: the technique does not stop at identifying problems but reveals causes that are specific enough to serve as the base for improvement measures. The only input that the analysis has is the three main problem areas that Section 5.1 describes. This, so that this analysis can confirm the already existing understanding, but without any bias on what the causes can be. This creates more reliability on the final establishment of the root causes.

During these interviews, respondents explain why each problem occurs, and the questioning continues until no further explanation can be given. We analyze the results by comparing them to the already established problems and causes. While most problems are only caused by one problem area, some causes influence more than one problem area; these are identified as cross-cutting issues.

Combined with the BPMN models and interview findings, the Five Why analysis clarifies the underlying mechanisms behind the main problems. It enables a complete view of where and why complications emerge.

5.3 Fishbone Diagram

The final step integrates the causes established in Sections 5.1 and 5.2 into a comprehensive Fishbone Diagram (Figure 10). This diagram visualizes which causes relate to each of the main problems. Overall, most problems contribute to one main problem area. Problems 9, 10 and 11 are cross cutting problems, as they influence more than one main problem. Additionally, the first two main problem areas contribute to the third problem area. When parts are not available or incorrect parts are available, the Mechanic Technician is not able to execute his tasks efficiently. Improving the main problem “parts not available” and the main problem “incorrect parts” also improves the final main problem. As the causes that fall under the third problem do not contribute to the first and second problems, they are still visualized as separate problems in the Fishbone Diagram.

Together, these results present a complete picture of which causes relate to each of the main problems that contribute to the preventable internal delays in the cleaning tool fulfillment process.

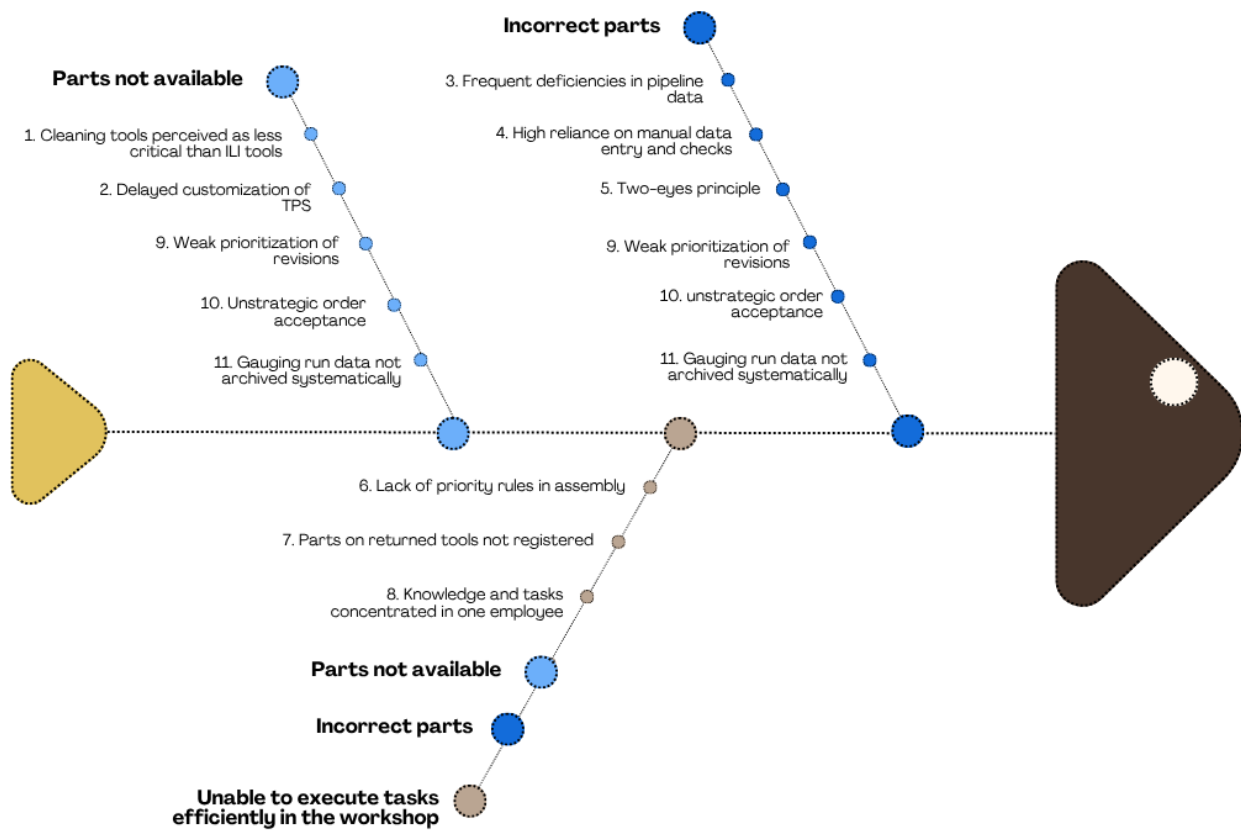


Figure 10: Fishbone diagram with main causes of internal delays

These findings form the foundation for developing improvements. The next chapter discusses the problems in more detail, explains how these contribute to the main problem, and translates them into concrete improvement opportunities.

6. Improvement opportunities

This chapter answers the question, “*How can the identified root causes of internal delays in the cleaning tool fulfillment process be addressed through targeted improvement opportunities?*” The analysis of Chapter 5 reveals that ROSEN Europe B.V. faces problems that limit efficiency and reliability in the cleaning tool fulfillment process. This chapter presents a set of improvement opportunities to address these challenges. Section 6.1 gives all the improvement opportunities linked to the root causes of the first main problem: parts not available when required. Section 6.2 presents the improvement opportunities for the second main problem: incorrect parts delivered, and Section 6.3 lists and explains the improvement opportunities that link to the root causes of the third main problem: unable to execute tasks efficiently in the workshop. Subsequently, Section 6.4 presents all improvements to cross-cutting problems. Finally, Section 6.5 provides a clear implementation approach.

6.1 Parts not available when required

The availability of parts is one of the most critical bottlenecks in the cleaning tool fulfillment process. Delays in part availability directly affect the ability of mechanics to complete assembly as planned. To address the recurring unavailability of parts, we design the following improvements as solutions for ROSEN. The numbering of the following improvement opportunities leads back to the problem numbering in Figure 11.

1. Formalize the role of cleaning tools in project kick-off meetings

A recurring cause of part shortages is that cleaning tools are perceived as less critical than In-Line Inspection (ILI) tools. This already becomes clear in the early stages of the cleaning tool fulfillment process. During project kick-off meetings, cleaning tools are often not discussed in detail, which reduces their visibility and priority throughout later phases. Several interview respondents emphasized that this “sets the tone” for the entire process: if cleaning tools are overlooked at the start, their requirements are also addressed too late downstream. Which causes stakeholders to prioritize processing the ILI tools.

Business Process Management principles emphasize that alignment before conducting a process prevents downstream errors and delays (Dumas et al., 2018). This confirms that the improvement needs to ensure the importance of cleaning tools at the beginning of the process, pointing to the kick-off meeting, as this is the first moment where an order is discussed with more stakeholders within the cleaning tool fulfillment process.

Formalized cleaning tools as a fixed agenda point in every kick-off meeting ensure that stakeholders explicitly confirm whether a cleaning tool is required, review critical data, and identify long-lead or scarce parts at the earliest possible stage. A relatively simple and standardized

list to follow, creates alignment between the departments. This guarantees that everyone is up-to-date and does not have to ask unnecessary questions later in the process, which causes time-loss.

2. Prioritization rules for TPS customization

Delays in part availability often originate from late completion of the Tool Preparation Sheet (TPS). Procurement cannot begin until the TPS is finalized; however, in practice this step is often postponed. At the moment, the customization of the TPSs follows the Earliest Due Date (EDD) scheduling theory. This due date is linked to the SDR. This works for “simple” orders but overlooks tools that need parts that have long lead times or complex setups, which then arrive too late and cause unnecessary delays. Especially when there already are backlogs, this even becomes a bigger problem.

Different scheduling rules offer alternative approaches. Earliest Due Date (EDD), similar to Earliest Release Date (ERD), First Come First Served (FCFS), and Longest Processing Time (LPT) each optimize different aspects of the workflow. Research indicates that no single scheduling rule performs best in all cases (Pinedo, 2022).

Based on these insights, sticking only to EDD keeps the process simple but overlooks the impact of other things. However, if only LPT is used, complex orders get priority while urgent ones are delayed, which makes the process less flexible. A mix of both methods offers a more balanced approach.

The improvement opportunity introduces a prioritization framework that integrates EDD with LPT logic. Procurement preparation now accounts for tool complexity, customer criticality, and the presence of long-lead components in addition to their due date. Complicated orders receive earlier attention regardless of their later SDA (table 7), reducing late supplier deliveries.

6.2 Incorrect parts delivered

A second recurring bottleneck in the cleaning tool fulfillment process is the delivery of incorrect parts. This section proposes several improvement opportunities to reduce the risk of the delivery of incorrect parts.

3. Formal data verification step at project start

Another major source of errors is the inconsistent quality of pipeline data. As the interviews highlighted, incomplete or incorrect entries are common and often due to human error, unclear responsibilities, or insufficient verification. Because confidence in the data is low, employees recheck information multiple times across project phases, as can especially be seen in Figure 5 in Section 4.2.2. This constant verification consumes time and resources and still does not eliminate errors; as parts may still be ordered incorrectly or in an incorrect quantity.

The root cause analysis reveals that frequent deficiencies in pipeline data lead to repeated errors later in the process. Options, such as additional checks during procurement or assembly, would only detect mistakes after they had already caused delays. Juran et al. (1999) emphasize that early error prevention adds more value and is more effective than correcting errors during a process. Therefore, implementing an early verification step is the most efficient and logically justified improvement, as it tackles the issue at its source rather than its consequences.

Introducing a formal verification step at the start of each project ensures that pipeline data is complete, feasible, and ready for use in procurement and assembly. A review by a team consisting of the Survey Lead, Tool Lead, and a Supply Chain representative validates data quality from different perspectives. The Survey Lead confirms completeness, the Tool Lead checks technical feasibility, and the Supply Chain representative ensures usability for ordering and logistics. This joint responsibility improves data accuracy and prevents downstream errors later in the process.

4. & 5. Standardized templates with built-in controls

A lot of errors in part deliveries come from manual data entry and the fact that employees are responsible for checking their own work. Filling in pipeline data, order requests, and TPSs often consist of free-text fields, which are very prone to errors. Additionally, important tasks such as verifying part numbers or quantities of parts often depend on one single employee, which increases the chance that small mistakes remain unnoticed until they cause bigger issues later in the process.

Two possible approaches can address these problems. One approach is to apply the four-eyes principle; here, a second employee reviews and confirms the most critical steps before they are carried out and go through to the next step in the process. A double-checking (DC) step helps to minimize human error, which is the reason why it is widely recommended (Schwappach et al., 2016). However, this approach also increases both the amount of work and the higher need for more collaboration. Most employees do not have any time left beyond their own regular tasks; next to that, it can be challenging to manage, as a lot of these tasks are conducted on a daily basis.

A more efficient alternative is to reduce the need for manual checking altogether by standardizing data entry and embedding validation directly into the system. Standardized templates with built-in controls prevent many of the same errors that the four-eyes principle aims to detect, but without the additional time investment. An automated validation technique enhance data accuracy and integrity, leading to faster and more accurate processes and improve usability for employees compared to manual checking like the four-eyes principle (Sarat, S. et al., 2024). This approach allows employees to focus on their more value-adding tasks rather than repetitive manual checks.

By introducing drop-down menus, automated range checks, and pre-filled data fields, errors are automatically detected before they can affect later process steps. For example, the system immediately gives a notification when a pipeline diameter lies outside the expected range, while SAP numbers are retrieved directly from a central database.

6.3 Unable to execute tasks efficiently (Inefficient workshop tasks)

The execution of tasks within the workshop often is a major source of preventable internal delays. The improvement opportunities explained in Sections 6.1 and 6.3 also can contribute to reducing delays within the workshop. The following measures mainly contribute to reducing the inefficient execution of tasks, which also contributes to reducing delays within the workshop.

6. Introduce clear assembly priority rules

As Section 4.2.2 and Figure 9 also visualizes and highlights, at present, the Mechanic Technician (MT) often decides which tool to assemble next, based on the TDA and his own judgment. However, when parts are missing, the MT is forced to stop and initiate a change order. In practice, it happens that this cycle repeats itself multiple times. It happens that the assembly of multiple tools is started and stopped, leading to a much higher number of change orders compared to other ROSEN projects.

Options such as more supervision or a stricter deadline would not solve the underlying cause, as they again leave the decision dependent on the judgment of an individual. Studies show that assembly systems achieve the best results, when variability and uncertainty are minimized at the start of assembly. Requiring all components to be available before the assembly of a tool begins lead to higher throughput and reduced waiting times, especially in environments with a high part variability (Romero-Silva & Hurtado-Hernández, 2022). Because this problem is caused by unstructured decision-making, the most effective solution is to create a clear, objective rule that determines when the assembly of a certain tool is able to start. A rule that requires all necessary parts to be available before assembly begins directly eliminates the cause of these stop-and-start cycles.

The rule ensures that each assembly only starts once all required components are present and confirmed in the system. Each order number links to specific SAP numbers representing the parts needed for that tool. When every part linked to an order is delivered or already available in inventory, the system marks the order as ready to start. If parts are still missing, the order remains on hold. When the TDA approaches while components are still incomplete, the system can issue a warning so that priorities or alternatives can be reviewed and possibly be reported to a higher level of responsibility.

This structured approach creates clarity, prevents early starts, and reduces unnecessary change orders. In practice, ROSEN can label this approach as the “kit-ready rule”. “A kit is a specific collection of components and/or subassemblies that together support one or more assembly operations for a given product or shop order” (Bozer and McGinnis, 1992).

7. Register parts of returned tools

When tools are returned from clients, some parts remain attached to the tool body. There is currently no standardized procedure to register these parts into the inventory system. As a result, new orders are placed for components that are already physically available but not visible in the system. This creates as is called “ghost stock,” leading to duplicate orders, inefficiency, and confusion on the shop floor. Mechanics then spend additional time searching for components or waiting for deliveries, further undermining process flow.

Standardizing the registration of returned parts directly tackles the issue and prevents unnecessary ordering. Since this problem is focused on missing registration rather than missing stock, the most effective improvement is to ensure that all available parts become visible in the system. Interviews strongly suggest this improvement, where respondents explain that unregistered returned parts are a frequent source of inefficiency and frustration. Lean manufacturing principles emphasize the importance of this improvement, as studies stress to minimize all forms of waste, with a strong focus on inventory accuracy and making sure overproduction and unnecessary procurement are eliminated (Lakshmanan et al., 2023; Bizuneh & Omer, 2024)

The procedure requires that all reusable components from returned tools are either stripped from the body and rebooked into inventory or recorded as “attached stock” if they remain on the tool. Mechanics can perform this task during waiting periods, for example, when assemblies are on hold due to missing parts. Investing small amounts of time can already ensure smoother future operations and more reliable data across departments.

8. Training and knowledge transfer

In the assembly phase, knowledge is concentrated in one employee. He is the only one responsible for cleaning tools. This dependency makes the process vulnerable and results in tasks often not being able to be conducted efficiently. When crucial individuals are unavailable, progress slows, and delays start to build up. This problem results in little room for dividing tasks, forcing mechanics to wait instead of taking over work from colleagues.

An option for ROSEN could be to hire additional staff or to create detailed manuals. This however would not solve the underlying vulnerability, as the expertise would remain within one person, a training of this extra employee needs to be given either way, and higher costs will be involved. Lean manufacturing theories highlight that cross-training and workforce involvement empower employees to understand and manage multiple processes, reducing bottlenecks and reliance on individual workers (Marin-Garcia & Bonavia, 2014; Hopp et al., 2004; Altendorfer et al., 2020). Cross-training and structured knowledge transfer directly strengthen continuity by ensuring that essential skills are spread across multiple employees.

Targeted cross-training ensures that several employees can perform cleaning tool assembly tasks independently. The experienced mechanic in question can share his knowledge through short, practical sessions focused on key preparation and assembly steps. This enables the work to be distributed more evenly when needed. So, when unexpected absences or peaks in cleaning tools to be assembled occur, trained employees can take over tasks immediately, preventing delays. The time put in the practical sessions is saved again when another mechanic can step in when necessary.

6.4 Cross-cutting improvements

In addition to the targeted improvements discussed in Sections 6.1, 6.2 and 6.3, several systemic weaknesses cut across all stages of the cleaning tool fulfillment process. These issues affect multiple departments simultaneously and reinforce the recurring delays identified in earlier sections. Addressing these cross-cutting causes strengthens the overall stability of the process.

9. Standardize revision handling

Currently, revisions to TPSs, as explained in Section 4.2.2, are handled in an inconsistent and ad hoc manner. Changes are often communicated by email, while project folders remain underused. As a result, employees rely on memory or personal discipline to process updates, which leads to mistakes such as incorrect orders or parts being requested too late. Interviews confirm that the absence of one “leading” system regularly causes confusion, especially when multiple revisions exist for a single order.

The main problem comes from unclear communication and the lack of version control. Adding reminders of the revisions or stricter supervision could improve the problem in the short term, but this would not completely solve the problem. Another possible approach would be to automate the handling of the revisions through an ERP extension. Research, however, shows that full automation requires significant integration effort and only is suitable for processes with tasks that are rule-based (Heinrich et al., 2019; Shao et al., 2018; Schlegel et al., 2024). This is not the case, so this optional improvement can be eliminated. Standardization of processes and documentation is proved to reduce errors, improve quality, and increased customer satisfaction. Furthermore, it clarifies responsibilities. (Arslan et al., 2023; Nissinboim & Naveh, 2017). Therefore, standardizing the handling of revisions already provides a solid foundation for potential later automation and ensures improvement without the burden of major implementation effort, since the main issue is unstructured communication and a lack of version control.

So, the best approach is to implement a standardized procedure that consists of fixed steps for the submission of a revision, the impact of the revision on the rest of the process, its approval, and the communication of the revision. The project folder functions as the single source of truth, supported by system notifications that alert stakeholders when new revisions are uploaded.

10. Strategic order acceptance

A weak link between the sales department and project execution leads to unrealistic commitments. Orders are often accepted to maximize client satisfaction without fully assessing feasibility for the workshop or supply chain. This “service company mindset” creates recurring workload peaks and forces departments into “firefighting” mode. To be able to still meet the TDA, mechanics are often asked to work overtime, which is not a long-term solution.

A first possible option is to hire more staff as a buffer for when peaks occur in the workload. Although this may reduce the workload for a while, it does not solve the problem at its root. Another option is to set clear rules for the acceptance of orders, such as rejecting all orders placed within 30 days of the run date. This, however, would go against ROSEN’s service-oriented business approach and risks damaging client relationships. A third option is to automate order scheduling based on ERP system forecasts. This, however, only works when the data is always accurate, and the processes are consistent. This, unfortunately, is not the case.

In comparison, implementing a structured feasibility check at order intake directly tackles the root cause, the absence of coordination between sales and operational capacity, without reducing flexibility or requiring heavy investment. This approach ensures that each order is evaluated on feasibility before its confirmation in the sales phase, which aligns the commercial goals and commitments with the workshop’s realistic capabilities. Studies show that Capable-to-Promise (CTP)-based order acceptance models lead to more reliable delivery commitments by matching orders to actual resource availability, thus reducing missed deadlines. CTP evaluates each order against the capacity of the workshop, material availability, and lead times before its confirmation, ensuring that only feasible orders are accepted (Abedi & Zhu, 2020; Dumetz et al., 2016; Alemany et al., 2018). Another order-accepting model is the Available-to-Promise approach (ATP). This approach, however, does not consider capacity, which CTP does (Dumetz et al., 2016). This is crucial in the case of meeting the goal of a strategic order acceptance.

The existing internal guideline already provides a strong foundation:

- ≥ 90 days before run date: order can be completed under normal conditions
- 60 - 90 days: feasible depending on requirements
- ≤ 30 days: high risk for delays and reduced quality

Formalizing this guideline in a structured process ensures consistent decision-making. For orders within 60 or 30 days, the responsible departments assess potential adjustments of the requirements before confirming an order and discuss them with the client, such as adjusting run dates or modifying part requirements, to still maintain the service company mindset while avoiding unrealistic promises.

11. Systematic archiving of gauging run data

Gauging runs provide critical insights into pipeline deformations, which often differ from the existing pipeline data. At present, this updated data is used for the ongoing project but is not systematically archived for reuse. As a result, identical data must be requested repeatedly from clients or be completed, improved, or altered, creating extra work and delays.

The most effective and sustainable solution is to store the gauging run data in one structured database and ensure that in all projects the archiving step is a standard procedure. This way, information is saved for future projects.

A centralized knowledge database for gauging run data, combined with a mandatory evaluation and archival step after each run, ensures that insights are systematically documented and reused. Storing and sharing insights, strengthens organizational memory, supports faster project execution, and leads to better decision-making. When the stored data is used effectively, studies show that teams make fewer mistakes and deliver higher-quality results (Chhim et al., 2017; Schillebeeckx et al., 2020; Zhang et al., 2017).

Each project then contributes directly to a growing internal database that supports future tool customization and part selection. Making the Survey Lead responsible for the extra archiving step prevents the loss of crucial data and guarantees that someone can be held accountable.

6.5 Implementation approach

The proposed improvement opportunities differ in the amount of time and effort they take to implement. The improvements build on each other: first by strengthening the foundation of the process, then by improving collaboration and coordination between departments, and finally by ensuring that improvements become sustainable through knowledge sharing and ownership.

Phase 1: strengthening the foundation

The first step focuses on creating a process basis that is stable and reliable. This involves preventing problems from arising early in the project and ensuring all essential information is correct and accessible from the start. Introducing a formal verification step at the beginning of each project makes sure that pipeline data is complete and reliable before it enters execution. Similarly, using standardized templates with built-in controls reduces the chance of manual entry errors, while keeping documentation consistent and easier to check. At the same time, formalizing the role of cleaning tools during projects kick-off meetings ensures that these tools receive the same level of attention as other tools. This change strengthens early alignment between departments and helps procurement activities on time. Together, these measures form the base for more accurate planning, fewer late corrections, and a clearer process flow in later phases.

Phase 2: improving collaboration

Once the basic structure is in place, the next phase focuses on improving cooperation and coordination between departments. Many of the issues we identify originate from inconsistent communication or unclear task prioritization. Introducing clear prioritization rules for customizing the Tool Preparation Sheet (TPS) ensures that due dates and tool complexity are both considered, allowing for a more balanced workflow. Within the workshop, assembly priority rules make sure that technicians only start assembling when all required parts are available. This helps to prevent interruptions, repeated change orders, and unnecessary pressure on other ongoing projects. To further reduce confusion, standardizing the handling of revisions makes it easier for employees to identify the correct and most recent version of the TPS which directly supports smoother collaboration between the Tool Lead, Supply Chain, and workshop staff. This phase also includes registering parts on returned tools, which improves inventory accuracy and prevents reordering components that are already available. Finally, the introduction of strategic order acceptance aligns incoming projects with available capacity, creating a more realistic workload distribution between sales, project management, and the workshop. Together, these actions enhance coordination across functions, leading to fewer delays and more efficient handovers.

Phase 3: Building lasting reliability

The final phase focuses on sustaining the achieved improvements and increasing process reliability. Training and knowledge transfer help reduce dependency on individual employees and ensure that essential expertise remains available within the team. This strengthens flexibility in the workshop and reduces the risk of process disruption during staff changes or high workloads. Additionally systematic archiving of gauging run data allows relevant information to be reused in the future projects, avoiding repeated data requests and unnecessary delays. When combined with the improvements from earlier phases, this establishes a reliable feedback loop in which information and experience from past projects continuously improve future performance.

7. Conclusion, recommendations and further research

This chapter concludes the research presented in this thesis. It contains the key findings and recommendations resulting from analyzing the cleaning tool fulfillment process at ROSEN Europe B.V. Section 7.1 provides the main conclusion by first answering the research questions. Section 7.2 gives recommendations for ROSEN. Finally, section 7.3 offers suggestions for further research, based on the insights gained in this research.

7.1 Conclusion

This section first gives an overall answer to the main research question and then further answers this question by answering all sub-research questions.

The main research question of this thesis is:

“How can the cleaning tool fulfillment process at ROSEN Europe B.V. be analyzed and improved to reduce preventable internal delays?”

We answer this question by combining literature, a process analysis visualized by BPMN, relevant stakeholder reviews, and a root cause analysis. Together, they provide insight into the cleaning tool fulfillment process, the root causes of recurring internal delays and inefficiencies, and opportunities for improvement.

Research question 1: *“What is the current situation at ROSEN Europe B.V. regarding the cleaning tool fulfillment process, and which stakeholders are involved?”*

ROSEN assembles custom tools that prepare pipelines for inspection. The different tools are gauging tools, cleaning tools, and ILI tools. These tools consist of reusable bodies combined with project-specific parts. The fulfillment process starts after sales confirmation and includes several phases: planning, customization, procurement, and assembly. Many stakeholders are involved in the process, such as the Project Manager, Tool Lead, Shop Operations.

Research question 2: *“Which theoretical models and best practices can be used to analyze the cleaning tool fulfillment process at ROSEN Europe B.V., so that root causes for internal delays can be determined?”*

The research applies Business Process Management (BPM) and Root Cause Analysis (RCA) to analyze the process. BPM provides insight into how tasks and stakeholders are connected, while RCA focuses on identifying why problems occur. Within BPM, Business Process Model and Notation (BPMN) is used to visualize the process in a clear way. For RCA, the Fishbone Diagram and Five Whys technique can be combined to systematically identify underlying causes of delays.

These methods complement each other. Together, these models and practices form a structured and practical approach to determine the root causes for internal delays.

Research question 3: *“How is the cleaning tool fulfillment process at ROSEN Europe B.V. structured, and what are the dependencies between stakeholders?”*

The process model developed in this research shows that the cleaning tool fulfillment process consists of five connected phases: pre-execution, tool customization, pre-procurement, procurement, and tool preparation. Each phase involves multiple stakeholders with interdependent tasks. Project Managers coordinate overall progress, Tool Leads oversee the technical aspects, and the Supply Chain department handles material availability. The analysis highlights frequent handovers, repeated data verification, and ad hoc communication. The BPMN diagram shows the dependencies and reveals several issues within the process.

Research question 4: *“What are the root causes of the main problems of the cleaning tool fulfillment process, causing preventable internal delays?”*

Based on the interviews, follow-up interviews, and Five Whys, three main problem areas are identified with their root causes:

1. *Parts not available when required*

It often occurs that parts are not available when they are required. The following issues are root causes of this problem: cleaning tools are often seen as less critical than inspection tools, a delayed TPS completion is often the case, and there is a lack of prioritization. Cross-cutting issues that contribute to this main problem are weak prioritization of revisions, unstrategic order acceptance, and gauging run data not archived systematically.

2. *Incorrect parts delivered*

Next to the wrong quantity, wrong parts are also often delivered. A set of issues contribute to this problem: data quality issues, manual entry errors, and missing verification steps result in wrong or duplicate orders. Cross-cutting issues that contribute to this main problem are the same as those that contribute to the first problem.

3. *Unable to execute tasks efficiently in the workshop*

Tasks in the workshop can often not be executed efficiently due to several causes. Several problems are the cause of this main problem: the lack of priority rules in the assembly phase, parts on returned tools are not registered, and knowledge and tasks are concentrated in one employee. Next to that, the first main problems also contribute to the inability of efficiently executing tasks in the workshop.

Research question 5: *“How can the identified root causes of internal delays in the cleaning tool fulfillment process be addressed through targeted improvement opportunities?”*

We propose improvements that mostly aim at ensuring timely preparation, reliable data, and structured execution. These include formalizing the role of cleaning tools in project kick-off meetings, prioritization rules for TPS customization, a formal data verification step at project start,

standardized templates with built-in controls, introducing clear assembly priority rules, register parts of returned tools, training and knowledge transfer, standardizing revision handling, strategic order acceptance, and finally, systematic archiving of gauging run data.

The research shows that preventable internal delays at ROSEN Europe B.V. mainly result from unstructured coordination and limited process transparency. By combining Business Process Management and Root Cause Analysis, the fulfillment process can be systematically analyzed and improved. By introducing the overall improvement opportunities, ROSEN can shift from their now reactive problem solving to proactive process management in the future. The improvements mainly strengthen the collaboration between departments, reduce rework, and enhance the overall reliability of the cleaning tool fulfillment process.

7.2 Recommendations

Beyond the direct improvement opportunities, we would like to give several recommendations.

First, we would recommend to shift their blame culture. Promoting a culture of ownership within the organization can make a big difference. It means that employees take more responsibility when problems arise. Managers play an important role in this; they can really set the tone for the other employees. They can shift this blame culture by combining lessons learned and reflection sessions to finalize a project.

Furthermore, we recommend to strengthen data quality and availability. A recurring limitation was the lack of consistent and reliable data. ROSEN should invest in systematic data collection and registration, ensuring that delays, part availability, and revisions are recorded in a structured way. This would enable future analysis to support the qualitative insights with quantitative validation.

Finally, we recommend to expand improvements to related processes: Although this study focuses on cleaning tools, many findings are likely relevant for ILI tools and other product lines. Applying similar root cause analyses and improvement frameworks in these areas could yield broader organizational benefits.

7.3 Further research

The recommendations that Section 7.2 gives are already starting points for further research. Next to that, a couple of ideas are given in this section.

First, an idea for further research is exploring digital tools that reduce manual work and give faster insight. For example, a small predictive dashboard, automated checks on inventory, or quick, real-time forms for shop-floor updates. The research can focus on how these tools fit the cleaning tool process and what they do for speed and error reduction. A short trial in one team, with before and after data, would already give a lot of useful information.

Another idea for further research is to test different planning rules. Building an event simulation of the flow from procurement to assembly and compare scenarios, such as: current EDD-driven approach vs. the proposed mixed rule. This would give us a safe way to try options before changing the real process and help pick the rule set that works best under ROSEN's conditions and their variability.

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Appendices

Appendix A: Standardized questions

1. Can you describe your role in the cleaning tool fulfillment process? So, what are the main responsibilities you have during a project?
2. In your experience, what are the most common reasons for delays in the whole cleaning tool process?
3. Do you experience delays in your own work, and if so, what usually causes them?
4. When problems or delays occur in your work (in the cleaning tool assembly process), what do you think are the underlying reasons/ what do you think causes them?
5. When problems arise, how are they usually handled in your team?
6. Who do you think is responsible for ensuring that issues are resolved?
7. How is communication and coordination organized with other departments?
8. If you could change things in the process to reduce delays, what would it be?

Appendix B: Interviews

Respondent 1:

I: “Can you describe your role in the cleaning tool fulfillment process? What are the main responsibilities you have during a project?”

Respondent 1: “I am a project manager. My role is to take over projects after they are sold by Sales. From that point, I am responsible for the entire execution together with the project team. This means ensuring that the project scope is clear, aligning with customers, and making sure the tools, including cleaning tools, are ready on time.”

I: “So you are responsible from handover until final delivery?”

Respondent 1: “Exactly. Sales often determines the big picture—contract, deadlines, promises to the client. But as Project Manager, I make sure everything is actually executed. If we see that something is not feasible, we can still make adjustments with the project team. My job is to clarify all details and make sure execution is realistic.”

I: “And how does this relate to cleaning tools specifically?”

Respondent 1: “In 99% of inspection projects, cleaning tools are also needed. So for us, cleaning tools are part of almost every project. We plan them, coordinate their availability, and make sure they are included in the schedule. If a cleaning tool is delayed, the whole inspection can be delayed, so it’s critical.”

I: “In your experience, what are the most common reasons for delays in the whole cleaning tool process?”

Respondent 1: “The most common issue is that parts are not delivered on time. Often this comes from the tool prep sheet being made too late. Without the tool prep sheet, no orders can be placed, and that means delays. The sheet is sometimes only created shortly before assembly, either because the project had little time, or because not all information was available yet.”

I: “So the root cause is that the prep sheet is not prioritized enough?”

Respondent 1: “Yes, I would say so. If we finalize the prep sheet earlier, the purchasing department can order parts earlier, and we have more time to react if something goes wrong. Right now, the delay often comes from the prep sheet being last-minute.”

I: “Are there other causes besides the prep sheet?”

Respondent 1: “Yes, quality control of incoming parts is not always good. Sometimes we receive parts that don’t meet requirements, which also causes delays. And of course, human error plays a role, sometimes orders are simply placed too late.”

I: “Do you experience delays in your own work, and if so, what usually causes them?”

Respondent 1: “Yes, absolutely. Many times we only realize too late that parts cannot be delivered by Lingen in time. At that moment, the project team can’t do much anymore. We depend on the supplier’s delivery, and sometimes we are simply stuck waiting. Another cause is

that projects often come to the project team very late after the contract is signed. That means we already start execution with time pressure.”

I: “So you are already under stress before the project even starts properly?”

Respondent 1: “Exactly. By the time the project reaches us, deadlines are often very tight. That makes it much harder to deal with any issues along the way.”

I: “When problems or delays occur in your work, what do you think are the underlying reasons?”

Respondent 1: “The underlying reason is organizational. There is too little feedback and too little documentation of mistakes. Problems are noted down in systems like Intellect, but people use this too little. That means the same mistakes keep happening. Also, there is not enough communication between departments. For example, when Sales promises something, the project team is often not consulted about feasibility. So we inherit problems that could have been prevented.”

I: “Why do you think the same mistakes keep happening? What’s behind it?”

Respondent 1: “Because of time pressure. Everyone wants to move fast and get the job done, so they skip documentation or feedback. But that means we don’t learn as an organization. So the root cause is really structural: lack of proper knowledge sharing and reflection.”

I: “When problems arise, how are they usually handled in your team?”

Respondent 1: “Usually, once we discover a problem, we escalate step by step. First we try to find internal solutions, maybe alternative parts, or shifting the schedule. If that doesn’t work, we escalate to Lingen to see if they can accelerate production or shipment. If still unresolved, it goes back to the project team to decide how to handle the customer communication. But the problem is often that we discover the issue too late, when options are limited.”

I: “So most of the time you are reacting instead of preventing?”

Respondent 1: “Exactly. That’s the issue. We react instead of proactively identifying risks earlier. By the time we are reacting, it often means higher costs, stress, and inefficiency.”

I: “Who do you think is responsible for ensuring that issues are resolved?”

Respondent 1: “Ultimately, the Project Manager is responsible for the entire project from start to finish. That means we are accountable for delays, costs, and outcomes. But responsibility should also be shared: work preparation, purchasing, and scheduling all have a role in preventing problems. Right now, the PM is often left to ‘fix’ everything, even when the root cause lies earlier in the chain.”

I: “So you think the accountability is too concentrated on the PM?”

Respondent 1: “Yes. The PM carries the full responsibility, but the actual causes are often outside our control. For example, if a part is not delivered in time because the prep sheet was late, or because quality control failed, that is not something the PM can influence directly. Still, we are expected to make sure the customer doesn’t notice delays.”

I: “How is communication and coordination organized with other departments? Where do the handovers typically take place?”

Respondent 1: “The main handover is from Sales to the Project Team. That is where many problems start, because information is incomplete or unrealistic promises are made. Within the project, handovers happen from the project team to work preparation and purchasing. But the communication there is not always efficient. For example, tool prep sheets are often delayed because they depend on engineering information. If engineering doesn’t deliver on time, purchasing can’t order, and everything shifts. We also see poor feedback loops, issues are not always reported back to the project team, so lessons aren’t learned.”

I: “So the weak link is really at the interfaces?”

Respondent 1: “Yes, exactly. The interfaces between departments are the bottlenecks. Each department focuses on their own task, but doesn’t always take responsibility for the overall timeline.”

I: “If you could change things in the process to reduce delays, what would it be?”

Respondent 1: “First, I would make the tool prep sheet a higher priority. If that document is ready earlier, purchasing has more time to order parts, and there is more flexibility to solve issues. Second, I would improve quality control of incoming parts, make sure defects are discovered immediately, not only when assembly starts. And third, I would push for better documentation and feedback, so that recurring mistakes are avoided. Right now, too many lessons are lost.”

I: “And what about organizational culture, do you think that plays a role?”

Respondent 1: “Yes, definitely. We often rely too much on firefighting, solving problems when they appear, instead of preventing them. That’s a mindset shift we need to make. Better preparation, more realistic planning, and stronger feedback loops would already save us a lot of time and cost.”

I: “Is there anything else you would like to add?”

Respondent 1: “Just that cleaning tools are sometimes underestimated compared to inspection tools. They are seen as simple, but in reality they are critical. If cleaning tools are delayed, the inspection tool can’t even go into the pipeline. So they should be treated with the same seriousness and preparation as other tools.”

I: “That was the interview, thank you very much for your time and answers!”

Respondent 1: “No problem!”

Respondent 2:

I: “Can you describe your role in the cleaning tool fulfillment process? What are your main responsibilities during a project?”

Respondent 2: “I work in procurement for the Europe region, which also covers Africa, India, and the former Soviet states. My team is responsible for purchasing everything: tool parts, travel, shipping, and inventory. For cleaning tools specifically, we receive purchase orders from the system once the project has been scheduled. We check if the required parts are in stock, and if not, we order them, mostly from Lingen, which is our main supplier. Orders are then handed over to colleagues like Frank and Andreas, who coordinate with the shop.”

I: “So you mainly make sure the right parts are available at the right time?”

Respondent 2: “Yes, exactly. That’s our role. We don’t assemble, but without us ordering the parts correctly and on time, the shop cannot start.”

I: “In your experience, what are the most common reasons for delays in the whole cleaning tool process?”

Respondent 2: “The most common problem is that parts are not available when needed. Sometimes they are ordered too late, sometimes the wrong parts are ordered, and sometimes Lingen can’t deliver in time. Another issue is that cleaning tools are reused, so parts like brushes and spacers may already be on a body, but this is not always documented correctly. As a result, we think we need to order them again, which creates confusion or double orders.”

I: “So late ordering and poor visibility of existing parts are the main reasons?”

Respondent 2: “Yes, exactly. The tool prep sheet is key here; if it’s ready late, then we also start late. That has a knock-on effect on everything.”

I: “Do you experience delays in your own work? And if so, what usually causes them?”

Respondent 2: “Yes, we do. One cause is late or unclear information from the project team. If the tool prep sheet arrives too close to the TDA, we don’t have enough time to order. Another cause is supplier issues, especially with PU or brushes. PU often takes six weeks to deliver, sometimes longer if it has to come from the U.S. if the lead time isn’t considered in planning, then we automatically run into delays.”

I: “So even if you order correctly, the lead time itself can still create problems?”

Respondent 2: “Exactly. That’s why early preparation is so important. If we know earlier, we can place the orders earlier and avoid most of the issues.”

I: “When problems or delays occur in your work, what do you think are the underlying reasons?”

Respondent 2: “Most of the time it’s poor preparation. Either the information is incomplete, or there isn’t enough time between sales handing over a project and the actual execution. In theory, assembly is scheduled 60 days before the TDA. But in practice, the tool prep sheet is often finished much later, which leaves very little buffer. If anything goes wrong, for example, if Lingen can’t deliver on time, we have no room left to solve it. The system also relies too much

on people filling in information and communicating. Mistakes or late updates are not always documented properly. For example, we have systems like ROCOM and SharePoint, but not everyone uses them consistently. Some things are still shared by word of mouth. That's risky, because once information is missed, it doesn't get corrected until it's too late."

I: "When problems arise, how are they usually handled in your team?"

Respondent 2: "The first step is usually to check alternatives. For example, can we use a similar part that we already have in stock? If not, we escalate to Lingen and ask if they can prioritize the order or ship faster. If that still doesn't work, then we discuss it with the customizer and the project manager to see if a revision is possible, for example, using a different brush size or a slightly different part. In the worst case, we delay the project, but that happens very rarely because we try to avoid it at all costs."

I: "So there's a kind of step-by-step escalation process?"

Respondent 2: "Yes. First look internally, then check with Lingen, then escalate to the project manager if nothing else works."

I: "Who do you think is responsible for ensuring that these problems are resolved?"

Respondent 2: "Ultimately, the project manager is responsible for the project as a whole. But within supply chain, it's our responsibility to ensure that the ordered parts arrive on time. If something goes wrong, we need to flag it immediately. At the same time, the shop and maintenance also play a role. For example, if they don't check properly whether a part is already on a returned cleaning tool, that creates unnecessary extra work for us. So really, it's shared responsibility, but the project manager is the one who has to make final decisions."

I: "How is communication and coordination organized with other departments? Where are the handovers?"

Respondent 2: "Most of the coordination happens between us, the shop, and the project team. When a tool prep sheet is ready, it comes to us. We then create the purchase orders and inform Frank and Andreas, who coordinate with the shop. The handover is critical, if information is missing at that point, delays are almost inevitable. We also use the RINV (Regional Inventory) team chat to flag urgent issues. But not everything is documented properly, so sometimes communication is verbal or ad hoc. That creates gaps."

I: "So better documentation and earlier communication would help?"

Respondent 2: "Absolutely. If all changes and problems were properly entered into the system and shared with everyone, a lot of delays could be avoided."

I: "If you could change things in the process to reduce delays, what would it be?"

Respondent 2: "The biggest improvement would be earlier preparation of the tool prep sheet. If that's ready earlier, we can order earlier, and most delays would disappear. Also, we should have better visibility on what's already available on returned cleaning tools. Right now, cleaning tools are booked into the system as just the body, but they often still have parts like brushes or

magnets attached. If those parts were identified and booked into the system, we wouldn't order them again unnecessarily. That would save both time and cost."

I: "So more accurate stock visibility and earlier planning are the key points?"

Respondent 2: "Yes, exactly. And maybe in the future a more automated system that shows clearly: this part is available, this part is not, so you need to order it. That would really help to avoid the current confusion."

Respondent 3:

I: "Can you describe your role in the cleaning tool fulfillment process? So, what are the main responsibilities you have during a project?"

Respondent 3: "We order the parts, that is the main task. Additionally, we check whether we have new parts, especially for cleaning tools. That is my focus: ordering and checking parts."

I: "How is communication and coordination organized with other departments?"

Respondent 3: "If a cleaning tool is not plausible, we contact the customizer. And if there are special issues, for example a PDL or a spider nose, then we consult the mechanics for advice."

I: "In your experience, what are the most common reasons for delays in the whole cleaning tool process?"

Respondent 3: "If the cleaning tool arrives on time, there is no problem. Problems often arise from short-term requests or surprises, for example when a basebody is not available. Sometimes parts are incorrectly booked in the system, under the wrong SRP number. Then you think you have the correct part, but that turns out not to be the case. These are human errors. Additionally, we often have problems with PU or brushes. PUs from the US take about 6 weeks to deliver, brushes 3 to 4 weeks. Transmitters can also be an issue: they are assets and constantly circulate. Sometimes they are all in use and then you don't have one in stock."

I: "And if transmitters are missing, what do you do?"

Respondent 3: "Then we look for alternatives, such as another type of transmitter, or we use an adapter. Sometimes there is nothing you can do; it is just Murphy's law that everything is needed at the same time."

I: "When problems arise, how are they usually handled in your team?"

Respondent 3: "The first step is always to look for alternatives. The second step is to consult with the customizer: what can we adjust, which PU can we use? If there is no solution, the problem goes to the project manager. But usually we try to solve it ourselves first."

I: "When problems or delays occur in your work (in the cleaning tool assembly process), what do you think are the underlying reasons/ what do you think causes them?"

Respondent 3: "We are not flexible enough, because we do not have enough parts in stock. Deliveries from Lingen are insufficient. Actually, there should be a larger buffer, more stock. And there should be more standard parts, instead of special parts for each pipeline diameter. Now we have too many exceptions, and that makes it inefficient."

I: "Do you see revisions as a problem?"

Respondent 3: "Not really. Revisions happen, but usually that goes fine. With cleaning tools you can't change that much: it's about PUs or a PDL. Small things."

I: "Who do you think is responsible for ensuring that issues are resolved?"

Respondent 3: "First, I try to solve it myself. If it doesn't work, I go to the customizer. If there is still no solution, then it goes to the project manager. But usually we or the customizer can solve it."

I: "If you could change things in the process to reduce delays, what would it be?"

Respondent 3: "Better communication, especially from project management to tool leads and customizers. If the information is available early, we have fewer problems. And time is the biggest issue: if we have enough time to order parts, it always works out."

I: "And how is contact with the mechanic technician?"

Respondent 3: "If there is a change or revision, we look at his prep sheet and discuss with him whether it is correct. Sometimes he has the wrong version, but usually it goes well. He is very experienced, actually the expert in cleaning tools."

I: "When do others come to you with problems?"

Respondent 3: "For example, when they have the wrong parts. Then I check whether the correct parts are still in stock. If not, we look for alternatives. We always try to solve such problems immediately, but sometimes we have to set priorities."

I: "And how do you handle changes?"

Respondent 3: "If we find an alternative, we write a change and discuss it with the customizer. If a change comes in via e-mail, we check the TDA and determine what is possible. Everything comes through us; we always check whether action is needed. We also often talk about this with Baris."

I: "Are there specific problems you often encounter in practice?"

Respondent 3: "Yes, sometimes bodies are not in the system. You then have to physically check whether they are present and in good condition. Many bodies have no number, which makes it difficult. It also happens that parts return from customers but are not properly booked. Then you think you have stock, but that turns out not to be the case. These are small errors, but together they cause a lot of extra work."

I: "And what do you do when it becomes clear that parts will not be delivered on time?"

Respondent 3: "Then we first contact Lingen, often via the coordinator. We try to make clear that the project is important. If it really cannot be done, we look for alternatives. Sometimes that works, sometimes not."

Respondent 4:

I: “Can you describe your role in the cleaning tool fulfillment process? So, what are the main responsibilities you have during a project?”

Respondent 4: “My responsibilities are mainly coordinating the tasks and projects within the shop, including those related to cleaning and gauging. I also provide the correct information to the customizers, ensure that the parts for the cleaning tools are up to date, and align the planning. Officially, as a tool lead, I hold final responsibility for delivering the tools from the shop on time.”

I: “So you are basically responsible for everything that needs to happen in the shop?”

Respondent 4: “Yes, you could put it that way. We are the bridge between the shop and the projects.”

I: “What do you see as the most important steps in the cleaning tool process from your perspective?”

Respondent 4: “The most important thing is that tasks are requested on time. Everything runs through tasks in the system, which also contain all the information. My main task is to make sure that this information is as accurate and complete as possible: pipeline data, schemes, planning, quantities, spare parts.”

I: “In your experience, what are the most common reasons for delays in the whole cleaning tool process?”

Respondent 4: “The main cause is that parts do not arrive on time. In addition, the planning sometimes changes unexpectedly. You can’t completely separate it from ILI tools either: cleaning always comes before ILI. Another factor is FIPS. They focus only on cleaning and sell cleaning campaigns, especially for pipelines. If a pipeline is very dirty and our standard cleaning tools are not sufficient, it has to be referred to FIPS. They then set up a separate cleaning campaign and sell that to the customer. That has to be arranged through the project manager and sales.”

I: “Do you also experience internal problems within the cleaning tool process?”

Respondent 4: “Yes, a major risk is that most knowledge is concentrated with one person in the shop. He can assemble the tools well and adjust parts, but he doesn’t handle orders himself. If he is absent, the process gets stuck. In addition, we sometimes receive parts from Lingen that do not fit. He can often fix that, but in reality, the parts should be delivered correctly right away. Right now, we are too dependent on him.”

I: “So there should be more safeguards in place?”

Respondent 4: “Exactly. We have too many variations in parts, especially PU setups, which creates many risks. There should actually be better lifecycle management. Some parts developed

twenty years ago are still orderable, even though they should be obsolete. That increases the chance of errors.”

I: “And how does it go with the customizers and the ordering of parts?”

Respondent 4: “With the customizers it usually goes well, especially for standard cleaning tools. But the translation into actual orders often goes wrong. Parts are not ordered or ordered incorrectly. Everything is done manually by the coordinators: SAP numbers, WBS numbers, quantities. That is very error-prone. If something goes wrong, a new order has to be placed, and that costs time. Sometimes we have to pull parts from existing tools or look for alternatives.”

I: “You mentioned earlier that things often go wrong in the ordering process. How does the shop usually find out about that?”

Respondent 4: “Often they notice it themselves and then go to the coordinators. The person with most shop knowledge is hardly involved, since he doesn’t handle the systems well. If something goes wrong, the coordinators check what is still possible. Sometimes they look for alternatives at other locations, sometimes they escalate to supply chain for help with Lingen or elsewhere.”

I: “When do issues get escalated to you as tool lead?”

Respondent 4: “Usually only when there are no other options left. Then the coordinators come directly to me and ask: ‘Can we move the TDA? Because the part won’t arrive in time.’ That’s really the last thing we want to do, because it means renegotiating with the customer and the project team. But sometimes there’s no other solution.”

I: “So you are actually taking over work from the coordinators?”

Respondent 4: “Yes, exactly. We look for alternatives, because the coordinators are overloaded. Even in our shop, parts are lying everywhere – under tables, in racks, outside with the cleaning tools – and it takes huge amounts of time to find them. Recently I had to search outside for PU because it hadn’t arrived in time. That alone could be a full-time job.”

I: “Would it help if this were managed better in a system?”

Respondent 4: “Absolutely. Then you could see at a glance where parts are located. Officially, the parts stored outside should be entered into the system, but that often doesn’t happen. Last year there was a big catch-up effort where everything was entered, and that made it much clearer. That really helps.”

I: “Do you often encounter revisions?”

Respondent 4: “Revisions often arise from incomplete data in the system. Sometimes pipelines turn out to be more critical than expected, or a client later requests an additional gauging or cleaning tool. Then a new urgent request comes in, which disrupts the planning.”

I: “And how do you decide on priorities in such situations?”

Respondent 4: “Partly based on intuition. I often work on 15 to 20 projects at the same time. If I

know something can be done quickly, I handle it first. But if it has to come from Lingen, that always takes longer, and we don't get the highest priority. Some projects are more important, such as big projects with key clients those take precedence because millions are at stake. Smaller standard projects can usually be shifted a bit."

I: "Is the information in the handover and kick-off meetings always clear?"

Respondent 4: "Not always, and that's a real problem. In the kick-off you're supposed to get crucial information: fixed dates with the client, number and type of tools needed. If that isn't shared properly, we miss important details. Then we have to adjust prep sheets afterward or arrange extra parts. That costs a lot of time."

I: "I have heard that cleaning tools are sometimes seen as less important than ILI tools. Do you agree?"

Respondent 4: "Yes, that's true. A cleaning tool is seen as a simple tool: a base body with PU, brush, and sometimes magnets. It's often considered less critical. But the same strict requirements apply here. For example, with Atex regulations against explosion hazards. Sometimes all parts, even PU, must be Atex certified. If those requirements aren't communicated properly, it creates problems."

I: "When problems or delays occur in your work (in the cleaning tool assembly process), what do you think are the underlying reasons?"

Respondent 4: "It often comes down to incomplete or unclear data. For example, pipeline data is supposed to be finalized before the kick-off, but often it's not realistic. Sometimes placeholders are used, like a wall thickness of 80 mm or the number 9999. Officially, tasks shouldn't be requested without minimum data, but that minimum is too low. You actually need far more information to work properly. Also, the responsibility for complete data lies with survey leads, but the handover is often insufficient. Sometimes I fill in missing data myself if i'm sure, just to save time. But that's not how it should be done. The official responsibility lies elsewhere, often due to time pressure, we sometimes move ahead anyway."

I: "When problems arise, how are they usually handled in your team?"

Respondent 4: "Mostly ad hoc. We call Lingen, try to negotiate a new date, or shift the planning. If there's a factory acceptance test, it becomes extra difficult, because then everything stops, and the pressure is high. That costs a lot of time and money."

I: "Who do you think is responsible for ensuring that issues are resolved?"

Respondent 4: "Ultimately, I think it should be the project team and especially the survey leads for data issues. But in practice, the tool leads often absorb the problems. We coordinate and keep things moving. Still, the official responsibility lies elsewhere."

I: "How is communication and coordination organized with other departments?"

Respondent 4: "The most important handovers are from survey leads and project managers to

us. But if the information is incomplete, we run into problems later. There is supposed to be a clear chain, but in practice it's often informal or delayed. That makes it unreliable.”

I: “If you could change things in the process to reduce delays, what would it be?”

Respondent 4: “Better lifecycle management of parts, fewer obsolete variations. And especially better data quality from the start, so we don't lose time fixing mistakes. Also, a better system for tracking parts in the shop – where they are, what is available. That would save a lot of time and stress.”

I: “Thank you for your time and detailed answers.”

Respondent 4: “You're welcome, no problem.”

Respondent 5:

I: “Can you describe your role in the cleaning tool fulfillment process? So, what are the main responsibilities you have during a project?”

Respondent 5: “I work in the workshop, mainly on assembling cleaning tools. When a project starts, I check the planning to see which tool is scheduled, print the Tool Preparation Sheet, and make sure all the necessary parts are available. If something is missing, I contact logistics or supply chain to check what is going on. Once everything is complete, I assemble and test the tools to make sure they match the specifications on the prep sheet.”

I: “In your experience, what are the most common reasons for delays in the whole cleaning tool process?”

Respondent 5: “A big reason is missing or late parts. For example, when ITX-cages or other components arrive too late, we have to spend hours finding out where they are. Before you get an answer from logistics, you can already lose two hours. Another issue is that returned tools often still have parts attached, such as spacers or magnets, which are then ordered again by mistake. That creates double parts and a lot of rebooking work.”

I: “So delays often start because the parts are not available or wrongly ordered?”

Respondent 5: “Exactly. If all basebodies arrived stripped and clean, it would be much clearer what is needed. Now, half the time we discover too late that we already had the parts, but they just were not registered.”

I: “Do you experience delays in your own work, and if so, what usually causes them?”

Respondent 5: “Yes, very often. For example, sometimes parts are physically in the workshop but not booked in the system, so supply chain does not know they exist. Then we order new ones unnecessarily. Another example is revisions, they often come in too late or are processed incorrectly, so you cannot continue until the documentation is fixed.”

I: “What kind of problems do these revisions cause?”

Respondent 5: “Last week, we had eight orders planned. For several of them, parts were either not delivered or wrongly delivered. That stopped our work completely. Revisions can also come from wrong data in the prep sheet or mistakes by customizers. Sometimes we discover these errors ourselves while assembling.”

I: “When problems or delays occur in your work, what do you think are the underlying reasons?”

Respondent 5: “Many issues come from poor communication and unclear responsibilities. For example, only one person really knows the condition of returned tools. If he is not there, the process stops. Also, coordinators are overloaded, they have too many projects and cannot follow up properly. So when something goes wrong, we do not get feedback.”

I: “So communication and dependency on individuals are major issues?”

Respondent 5: “Yes, too much depends on one person. If that person is absent, everything stalls. It is the same with revisions, they should be checked by multiple people, but in reality one person handles them alone.”

I: “When problems arise, how are they usually handled in your team?”

Respondent 5: “Normally, we go to the coordinators or the tool lead, but since coordinators are too busy, people often go directly to others, like supply chain or customizers. Everyone takes their own shortcut to get things done faster. But that creates miscommunication, because sometimes multiple people are working on the same issue without knowing it.”

I: “That must create confusion. Can you give an example?”

Respondent 5: “Yes, once a revision changed the number of tools from two to one, but the ordering system still said two. Then we received double materials. Another time, someone used an outdated version of the prep sheet and had to rebuild an entire 40-inch tool.”

I: “Who do you think is responsible for ensuring that issues are resolved?”

Respondent 5: “Officially, the coordinators are, but in practice, it is shared between too many people. Everyone points to someone else. Sometimes we report issues, but nothing happens, so we solve it ourselves if we can.”

I: “How is communication and coordination organized with other departments?”

Respondent 5: “Mostly by email, but there is little structure. Supply chain checks availability only in the system, while logistics sees the physical stock. These do not always match. We are basically the third check, first supply chain, then logistics, then us. But even then, parts are still missing. There is also confusion about dates, like the TDA or SDR, because people shift them without informing others.”

I: “Why do people change dates themselves?”

Respondent 5: “They try to help, they think starting earlier will save time. But it often makes things worse, because the parts or documentation are not ready yet. Then you end up with half-finished tools and more change orders.”

I: “If you could change things in the process to reduce delays, what would it be?”

Respondent 5: “First, better registration of returned parts, so we know exactly what is in stock. Second, clearer planning, only start when all parts are available instead of beginning early. And finally, better communication between departments. Too often, everyone works in their own way without checking with others. If we had clear rules and better information flow, we could finish most tools in a few days instead of getting stuck on half of them.”

Respondent 6:

I: “Can you describe your role in the cleaning tool fulfillment process? So, what are the main responsibilities you have during a project?”

Respondent 6: “I work in procurement and handle orders. In practice, this means that maintenance makes the requests, and I check what is available. Sometimes there is a version with costs, sometimes without, depending on how the item is booked. That happens everywhere: the same part can exist in several versions. About 80% of the orders go through Lingen. These come in as purchases in Rosen Ordering, and we can still make adjustments with a change order.”

I: “And what can you change with such a change order exactly?”

Respondent 6: “Basically only the quantity, the date, or the recipient. Not the type of item. Sometimes that’s inconvenient: mechanics have to enter change orders themselves, but they don’t really know the system. That costs time and leads to mistakes.”

I: “So what are your tasks and responsibilities in the ordering process?”

Respondent 6: “I process the orders that come from the coordinators, they place the actual requests. I make sure the orders go through, or that changes are made when needed. I also stay in contact with the warehouse to make sure maintenance gets the items on time.”

I: “How is communication and coordination organized with other departments, for example with scheduling?”

Respondent 6: “Honestly, hardly at all. We try to get the parts in by a certain date, but scheduling is not directly involved. The warehouse delivers to maintenance, that’s the line.”

I: “Can you describe how an order is placed?”

Respondent 6: “It starts with a request from maintenance or the workshop. The system shows if something is in stock. If it is, it becomes an order. If not, it goes as a purchase order to Lingen. We use Rosen Ordering and SAP. In theory, we look at lead times, but often it’s just a guess. Officially you should order three weeks in advance, but usually it’s less. Sometimes we get parts delivered in one day, but then they must be ordered before 3 p.m.”

I: “In your experience, what are the most common reasons for delays in the whole cleaning tool process?”

Respondent 6: “The biggest challenge is communication. Maintenance reports delays via a whiteboard or Excel list, which goes through another colleague. But really it should come directly to us or to the coordinators. Change orders are also often submitted too late, leaving us no time to order.”

I: “How is communication with suppliers?”

Respondent 6: “With Lingen we have daily contact. They are the main supplier for tool parts.”

Our contact person there sees all orders from different regions. But delivery times vary enormously, which makes planning difficult.”

I: “How often do deliveries go wrong?”

Respondent 6: “Regularly. Often because orders are placed too late, or because there are errors in the system. Sometimes we only discover after booking out that certain parts were already on a body. Then they have to be reversed or canceled, which is extra work.”

I: “Do you experience delays in your own work, and if so, what usually causes them?”

Respondent 6: “Yes, often because information from planning comes to us indirectly. It goes via prep sheets and orders from the coordinators. If sales and engineering finish late, we get the requests late too. Then there is a lot of stress in the process.”

I: “When problems or delays occur in your work (in the cleaning tool assembly process), what do you think are the underlying reasons?”

Respondent 6: “The biggest inefficiency is the detour in communication. Maintenance writes things on the whiteboard, that goes to Excel, then through another colleague, and only then to us. That takes time and information gets lost. Another problem is that parts already on tool bodies aren’t flagged early enough. Then we book them out again even though that wasn’t necessary. That should be much better integrated into the process.”

I: “How are urgent orders or changes handled?”

Respondent 6: “In principle, changes must be in the system before 7 a.m. At 7:30 the warehouse refreshes and starts processing orders. If a change comes after that, it has to go through us in the RINV-chat, because the system can’t handle it anymore. That’s cumbersome and not ideal.”

I: “When problems arise, how are they usually handled in your team?”

Respondent 6: “We try to fix it as quickly as possible, but often it’s firefighting. If parts are missing, we check alternatives or escalate via the chat. If that doesn’t work, it’s back to the coordinators or to Lingen.”

I: “Who do you think is responsible for ensuring that issues are resolved?”

Respondent 6: “Ultimately the project manager for the whole project. But within procurement, it’s our job to ensure the ordered parts arrive on time. If something goes wrong, we have to flag it immediately. But others also play a role: mechanics should register parts on returned tools properly, otherwise we order unnecessarily. So responsibility is shared.”

I: “What improvements would you suggest to reduce delays?”

Respondent 6: “Better registration of which parts are already on the tools. Now tool bodies come back and are left outside the building without being entered into the system. As long as that doesn’t happen, we have no visibility. It should be a standard step to immediately register those

bodies. Also, stricter discipline with change orders would help: if they are in the system earlier, we can act faster.”

I: “Have there already been improvement initiatives?”

Respondent 6: “Yes, there are flowcharts being made to clarify the processes. And they’re looking into how prep sheets can be created faster, because that’s often the bottleneck. If sales and the coordinators finish their work earlier, the whole process runs smoother.”

I: “If you look back, what would deliver the biggest benefit for you?”

Respondent 6: “That mechanics don’t have to make change orders themselves, but that it’s integrated into the process. And that tool bodies are always registered immediately when they return. Then we would have much better visibility and could plan more efficiently.”

I: “Thank you for your time and answers.”

Respondent 6: “You’re welcome.”

Respondent 7:

I: “Can you describe your role in the cleaning tool fulfillment process? So, what are the main responsibilities you have during a project?”

Respondent 7: “From planning, I make sure the workload of tools per week is manageable. So, it’s mainly about distributing the workload.”

I: “And that is different for ILI tools compared to cleaning tools, right?”

Respondent 7: “Yes, that’s correct. For cleaning tools, we look per week at what is scheduled, and they are handled in chronological order. For ILI tools it’s more on a daily basis. We check ROCOM for the week’s requirements and based on that we plan the cleaning tools.”

I: “So for example: this week it makes sense to plan ten tools, and then you distribute them accordingly?”

Respondent 7: “Exactly. We get a request from the client, and we have to see if we can meet it with the capacity we have. One colleague is our dedicated resource for assembling cleaning tools. At the same time, we train others so we have more capacity if demand increases.”

I: “How is communication and coordination organized with other departments? Where do the handovers typically take place?”

Respondent 7: “Once the planning is made, it goes into the system, and the mechanic sees it directly through his own filter. He sees which tools are scheduled for him. I look at what’s scheduled from project planning: tasks come from there, and they are passed to the workshop. We then execute them.”

I: “In your experience, what are the most common reasons for delays or inefficiencies?”

Respondent 7: “Several things. First, human errors, like wrong orders or mixing up numbers. Then project planning and engineering: sometimes a design comes in far too late, which makes it unrealistic to have parts on time. And another issue is the lack of a proper check whether all parts are present. In ROCOM you don’t see at a glance if everything is there. Ideally you’d have a stoplight system: green means complete. Now you have to look in another system, and that often doesn’t happen. People only notice when a box number is requested.”

I: “So essentially a preparation step is missing?”

Respondent 7: “Yes, exactly. It’s a lack of ownership in work preparation. People often say they don’t have time, but it costs more time to fix issues later. Now it often happens that the mechanic says: ‘I’m missing two discs, so I can’t start.’ Then you still have to go back to preparation. That time is lost anyway, so it’s better to do it at the right moment.”

I: “So it’s also a matter of taking responsibility?”

Respondent 7: “Exactly. The problem is that too little responsibility is taken for doing that second check. If preparation was solid, we wouldn’t have to fall back. Now we often start on a

tool, then discover parts are missing, and the tool remains unfinished. Then another tool gets added, and so it piles up. That wastes time and creates the risk of losing track of things.”

I: “You also mentioned project planning, could you elaborate?”

Respondent 7: “Capacity needs to be safeguarded in advance. If a week already has ten large tools scheduled, you shouldn’t add more big tools. Right now it’s more of a gut feeling. For ILI tools we have clear numbers per week (eight to ten), but for cleaning tools not. That vagueness makes planning hard. There are no benchmarks for how long a cleaning tool takes. A small tool can take two minutes, or two hours, depending on the situation.”

I: “So there are no standards or benchmarks for cleaning tool lead times?”

Respondent 7: “No, and that makes planning difficult. It would help to have reference numbers, like: up to a certain inch takes this many hours. Then you could judge much better if planning is realistic. Now it’s vague, and people often just say yes, even if it’s not feasible.”

I: “And how do you see the availability of parts?”

Respondent 7: “For cleaning tools you’re less dependent on complex parts. It’s usually discs and spacers, which can be delivered within two weeks. But still, a clear check in the process is needed to prevent delays halfway.”

I: “Are there other inefficiencies you can name?”

Respondent 7: “It comes down to us having to redo steps that could have been avoided. Preparation and responsibility are lacking. Because of that, we often work with incomplete tools that remain lying around, causing unnecessary delays and inefficiency.”

I: “What do you think doesn’t go well in the process?”

Respondent 7: “Sometimes we start tools earlier than planned, and then we run into part shortages. That’s a problem in production planning. What should really happen is that second check: whether all parts are available before starting. That would solve 80% of the problems.”

I: “So with that check you mean simply whether the parts are in stock?”

Respondent 7: “Exactly. Because bodies with parts do lie outside, but those are not client specific. What’s outside has often been used before. Since the fire, we can’t just reuse everything. You don’t want to deliver second-hand material to the client. We’re too expensive for that.”

I: “Do you personally experience delays or inefficiencies in your work?”

Respondent 7: “Not directly. But I often have angry mechanics at my desk, saying they can’t work efficiently because parts aren’t there. I completely understand them. I can listen and promise improvement, and often it does get better. But one mechanic tends to start on tools for the next week without checking parts. He shouldn’t do that. Only if he first checks thoroughly. But he’s not great with systems.”

I: “So impatience among mechanics sometimes causes work to start too early?”

Respondent 7: “Yes, and then they get stuck. Tools remain half-finished, which creates frustration.”

I: “And you do monitor when a tool is delayed, right?”

Respondent 7: “Yes, we do. But we know preparation is under par, and that must be improved. The core is preparation: if that’s right, assembly runs smoothly.”

I: “So you’re saying the real problem is in preparation?”

Respondent 7: “Absolutely. Not only for cleaning tools, but also for ILI tools. The question is always: is what we want to do realistic? Can we actually do it? We don’t have a direct line with the factory to discuss. All we can do is inform them on time. That’s what we try. But in terms of efficiency: if preparation is correct, the rest flows automatically.”

I: “And what about setting priorities?”

Respondent 7: “Priorities only become an issue when capacity is full. Then we say: this first, the rest later. But normally that doesn’t apply. If parts are missing, you escalate to Lingen and ask for faster delivery. That’s escalation, not prioritization.”

I: “Why do you think these problems keep recurring?”

Respondent 7: “Because the burden often falls on the shop. It’s scheduled, and we’re expected to fix it. That’s the mindset. But I think we should prepare better ourselves. Then we wouldn’t have these problems. It’s the reality of a service company: the client calls with a problem, and we have to solve it. But you need to distinguish: are we delivering a top-class tool, or a basic one? That choice has to be made every time.”

I: “And who is held responsible when things go wrong? Just the shop?”

Respondent 7: “The older generation here still believes we always have to fix everything. But that’s not true. Without parts, you can’t make a tool. Then you just have to say so. If parts are on time, we can deliver. But the tension lies with project organization. They accept an order needing six weeks, and expect us to do it in two. That’s unrealistic. Then we get change orders afterward that we already saw coming.”

I: “Is that more a project management or coordinator issue?”

Respondent 7: “With the project organization in general. They pay too little attention to capacity. We can build 20 tools in a week, but then everything else falls away: no training, no reconditioning, no buffer. Realistically, we can do 8 to 12 per week. Management is starting to understand this better. There is now a year-long capacity plan showing visually what is possible and what is not. That helps.”

I: “Do you see a difference in how cleaning tools are perceived compared to ILI tools?”

Respondent 7: “Yes, cleaning tools are often seen as easy add-ons. But that’s not true. We also

need to consider quantity and size. The advantage is that for cleaning tools we often have four weeks, so we can balance them with ILI tools. Sometimes we even schedule them a week earlier to spread workload. That works well.”

I: “Can you explain what a revision means exactly?”

Respondent 7: “A revision means the original design doesn’t match or isn’t feasible with available parts. For example: you need a 20 mm spacer but only have a 15 mm one. You can’t just use that, it must be approved by the customizer. That’s a revision. Often it’s really a patch on poor preparation.”

I: “So missing parts lead to design changes?”

Respondent 7: “Yes, exactly. And also we don’t have good visibility of parts here. That leads to a lot of double ordering. Sometimes parts are flown in from abroad while they’re already here. That’s extremely expensive. But we also don’t want mechanics wasting time searching the whole day. Really, parts should be removed from bodies and booked into the warehouse. Then they’re visible. That idea exists, but it also costs time.”

I: “When problems arise, how are they usually handled in your team?”

Respondent 7: “We look for parts, ask Lingen to deliver faster, or make a revision with what we do have. But often we discover the shortage too late. The mechanic is on the critical path: what he finishes is shipped two days later. So if parts are missing then, you’re already too late. That causes stress. Sometimes we deliver a suboptimal solution: the client expects top class, but actually gets a lower version. They may not notice directly, but it’s not optimal.”

I: “So quality suffers, even if the client doesn’t always see it?”

Respondent 7: “Yes. The client experience is more about process: is delivery on time, is communication smooth, does the tool look good? But if we deliver with reused material, that sends the wrong signal. In extreme cases it happens, and you don’t want that.”

I: “And when it does go wrong, who is responsible for solving the problems?”

Respondent 7: “Initially work preparation. They can’t create a new design, but they look for alternatives and check with the customizer. Only then it escalates further.”

I: “If you could change one thing to improve the process, what would it be?”

Respondent 7: “A reliable stoplight system. A simple indicator showing whether all parts are available before starting. Everything depends on the parts. If you start without everything, you work inefficiently. I estimate that 30% of tools contain mistakes: ordered wrong, ordered too few, or forgotten. Those errors need to be eliminated.”

I: “And when do people usually come to you with problems?”

Respondent 7: “Mostly when parts are missing or the planning is overloaded. Often it’s the mechanic who comes to me. Sometimes also tool leads in preparation: then we look together

how to free capacity or add mechanics. It would help a lot to have standard time estimates per tool. Then we'd know how many hours each tool costs and could plan capacity better."

I: "And how does the planning work now?"

Respondent 7: "For cleaning tools we make a weekly plan based on the TDA. If the TDA shifts, the tool shifts. The mechanic also sees that in the system. He usually follows the plan, but sometimes starts on next week's tools. He's a hard worker, but creates chaos that way. That's why we're training him on ILI tools now, so he can use his energy there instead of starting cleaning tools too early without parts."

I: "So it's also about helping him to slow down?"

Respondent 7: "Yes, exactly. He does his work well and knows a lot about cleaning tools, but the approach must become more consistent. If he sticks to the planning, unnecessary problems are avoided."

I: "Thank you very much for your time and detailed answers."

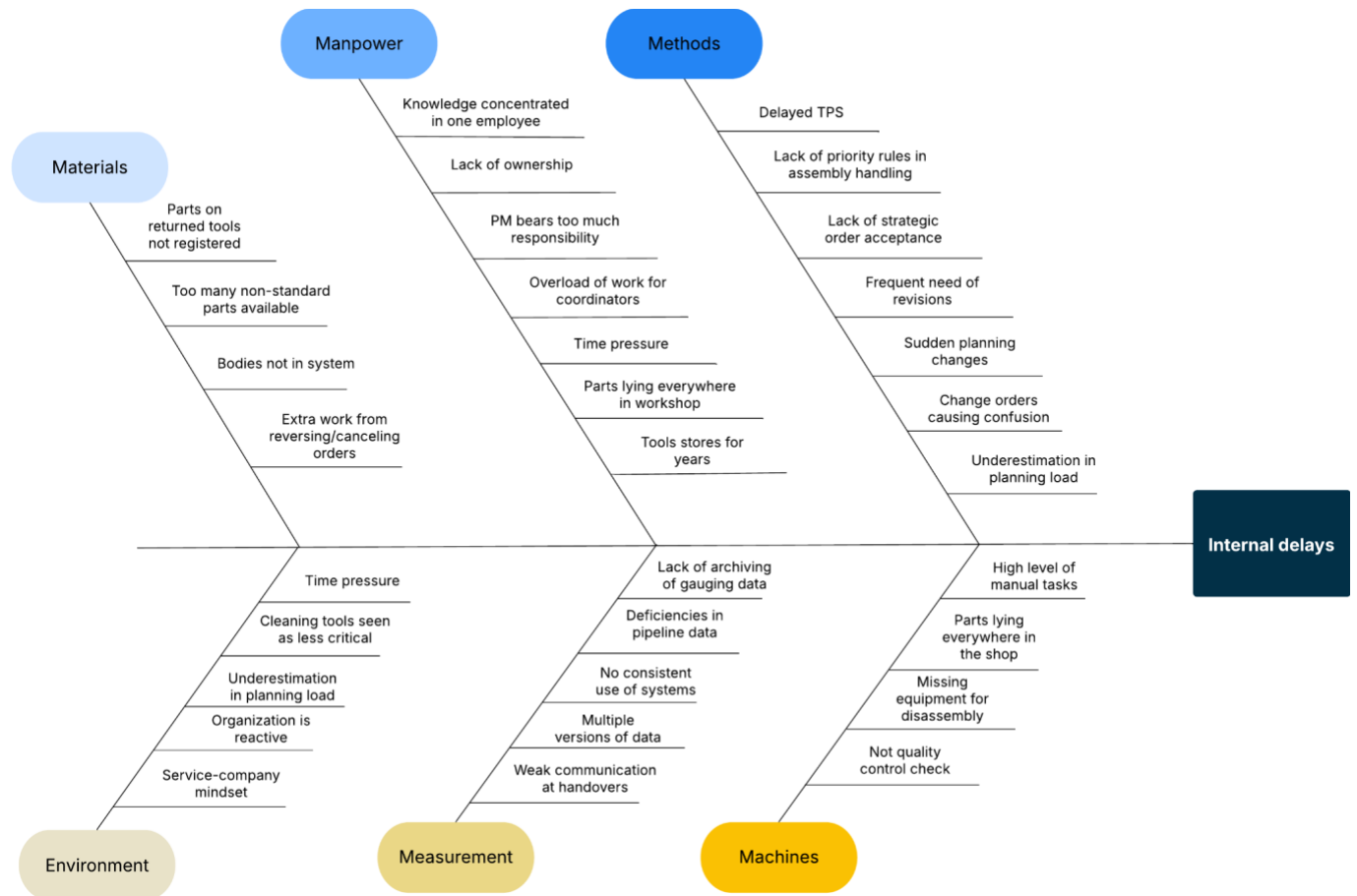
Respondent 7: "No problem, you're welcome."

Appendix C: Standard Fishbone Diagram

After the interview analysis, the research uses the Fishbone Diagram, as Section 3.2.3 describes, to structure identified problems. Instead of presenting an unstructured list of issues, the diagram helps to visualize relations and to ensure that different organizational aspects are considered.

The analysis organizes the problems according to the six classical “M’s”: Manpower, Methods, Machines, Materials, Measurement, and Environment. These categories are commonly used in industrial root causes analysis and ensure a complete and comparable overview.

Each category contains multiple problems derived from the interviews. This diagram already excludes issues outside ROSEN’s influence and excludes topics that fall under the responsibility of other departments than the focus of this research.



Standardized fishbone diagram of the cleaning tool fulfillment process

Appendix D: Use of generative AI

While writing this thesis, we used ChatGPT 2025 and grammarly to improve our writing style and structure. Every time a tool as such was used, we only used the text given as an idea, so we reviewed and edited the text to take full responsibility for the content of the work.