CHALMERS
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Analyzing the Creation of Process & Inspection Instructions at Volvo Cars

Identification and Reduction of Waste in the Administrative Process of Creating Assemble & Control Instructions for Cars

CORNELIUS HÄGG
Master's thesis in Production Engineering

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Master's thesis in Quality and Operations Management

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Cover: A office environment at Volvo Cars, picture retrieved from Volvo Cars press material

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Abstract

This project focuses on the challenges and opportunities in the car industry's shift towards electrification and evolving mobility behaviors. It underscores the significance of efficient processes, examining the case of Volvo Cars and the need to rectify inefficiencies in the administrative process of creating assembly instructions.

The project ensures research quality by employing a methodology involving participant selection through snowball sampling and recommendations, conducting a workshop to gather efficiency improvement suggestions, and employing data analysis techniques like value stream mapping, coding, thematic analysis, and stakeholder analysis. Drawing on a theoretical framework, it offers insights into enhancing efficiency in administration processes, optimizing process flows, managing product lifecycles, and embracing digital transformation.

The findings shed light on substantial inefficiencies in the current assembly instruction process, encompassing challenges in information search, system integration, waiting times, incorrect processes, overproduction, production of faulty services, and underutilized creativity. The project proposes improvements such as streamlined information transfer, enhanced system integration, standardized processes, and cross-functional collaboration to address these inefficiencies and enhance lean administration. The discussion highlights the thesis research quality and ethical considerations of the procedure and the thesis impact. It connects back to the research questions, discussing and analyzing the result with a Lean administration perspective and suggesting remedies for the identified inefficiencies.

As a result of its efforts, the project successfully identifies inefficiencies in the administrative processes of creating assembly instructions and develops improvement suggestions. The thesis result can be used to enhance productivity and quality assurance in the case company, serve as an eye opener to other organizations, and the approach can be applied in similar scenarios. However, further research is necessary to gain deeper insights into administrative inefficiencies across various industries, allowing the development of targeted strategies to enhance efficiency in both the public and private sectors.

Keywords: Lean Administration, Lean Office, Product Lifecycle Management, Value Stream Mapping, DevOps, Digitalization, Revision Control, Volvo Cars

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Cornelius Hägg & Stina Ljungberg
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List of Acronyms

Below is the list of acronyms that have been used throughout this thesis listed in alphabetical order:

AR	Augmented Reality
BOM	Bill Of Material
CC	Consequence Class
CO	Change Order
DRM	Design Research Methodology
EBOM	Engineering bill of materials
ESD	Electrostatic Discharge
IC	Incremental Change
ME	Manufacturing Engineer
P-FMEA	Process Failure Modes and Effects Analysis
PII	Process Inspection Instruction
PLM	Product Lifecycle Management
PL BOP	Plant Bill of Process
PR BOP	Product Bill of Process
PT	Process Time
R&D	Research and Development
ST	System Time
TPS	Toyota Production System
VBE	Virtual Build Event
VR	Virtual Reality
VSM	Value Stream Mapping

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1
Introduction

In this section, the background and general global impact of this master thesis will be presented, unveiling the project's importance and possible gain for other organizations and stakeholders. Moreover, the aim and research questions are introduced along with delimitations.

1.1 Background

The global car industry faces several challenges and opportunities with the transition towards electrification, autonomous technologies, connectivity, and changing mobility behaviors (Kuhnert et al. 2018, Stolfa et al. 2020). The intense race for change in the automotive industry, in unison with several new innovative competitors, creates a harsh market with high competitiveness for increasing and, even, maintaining the market share (NTT Data 2022). As for most cases with disruptive technologies (i.e., significantly altering the current market), it can be devastating for established organizations if they do not adopt the technologies which may become dominant (Lewis & Slack 2014).

Continuous improvement is a crucial aspect of Operations Management, playing a vital role in the long-term sustainability of organizations (Gremyr et al. 2020). Even leading companies may demise if they believe that their position keeps them safe from the need to improve (Gremyr et al. 2020). Operations Management is concerned with designing, measuring, and improving processes, thus creating processes that are both effective and efficient (Holweg et al. 2018). Effectiveness is determined by the customer's perspective, focusing on whether the process meets their expectations and efficiently utilizes resources (Holweg et al. 2018).

In addition to the previously mentioned challenges in the automotive industry, the industry is facing a shortage of semiconductors (Ramani et al. 2022), an unstable macroeconomic environment (Business Wire 2022, European Central Bank 2022), and a lack of competence (Paige-Stimson 2021). To engage in the realm of technical advancements, companies must confront an uncertain market and future. To stay competitive, they need to prioritize enhancing and redefining existing processes, ensuring they can adapt to the evolving landscape and effectively navigate the changes ahead.

The manufacturing system within the automotive industry has long been an area that has been studied and exposed to efficiency improvements with a primary focus on Lean Production and elimination of waste (Jasti & Kodali 2015). The Lean concept is not only applicable to manufacturing processes, it has also been spread to and been implemented in other areas such as administration processes (Larsson et al. 2008). However, the area of Lean administration is not well-researched even though the concept is described by practitioners. Some literature has been found on adapting Lean to administrative processes. For instance, Lean Administration by Larsson et al. (2008) and Value Stream Mapping, a common tool in Lean, in a DevOps perspective to become more suitable for software delivery processes (Tankhiwale & Saraf 2020).

With the understanding that waste, also called inefficiencies in this report, exists within manufacturing processes due to the well-researched topic, it is likely that waste occurs in administrative processes as well due to it being an area where practitioners apply Lean. Eliminating waste in administrative processes could have the same results as in manufacturing processes, e.g. improved quality and reduced cost and time. However, due to the research gap of Lean in administration processes, the extensiveness and effects are not as well explored.

The process of creating assembly instructions is one of many administrative processes that occurs in automotive companies. The instructions provide necessary information for the factories and can include a wide range of information from several departments, such as operation steps, tooling, quality controls, and models. The process of creating assembly instructions is of interest for performing an exploratory study on the topic of Lean administration due to its complexity. Furthermore, other industries and organizations may have similar processes, thus, this thesis can be seen as an indication of inefficiencies in similar administrative processes and the research procedure can be transferred to other settings, allowing others to reach their own unique results.

1.2 Case description

Volvo Cars is not an exception to the challenges, recent news describes challenges with the unstable world economy, increasing material costs, and increasing competition that Volvo Cars are facing (Volvo Cars 2023). The challenges cause the company to take further steps towards becoming a more cost-efficient company.

Furthermore, Volvo Cars are facing challenges in reorganizing the company to a manufacturer of electric vehicles and creating efficient and digitilized processes (Volvo Cars n.d.*a*). The challenge of digitalization entails that digital leaders have the tough task to redefine current analog processes into digital ones as well as create new processes in the new digitalized environment where none presently exists. Currently, as a part of the business development department, a lot of effort is being put into evaluating digitalized instructions for manufacturing operators and implementing digital aids such as AR, VR, and digital screens. Product and assemble process changes may therefore, in the future, be presented for the operators quicker and clearer, ensuring the quality of the production. This entails future demands on the data requirements of process instructions and interoperability, providing and utilizing information in a streamlined information flow. This means that the process of creating and handling process instructions needs a drastic overhaul to meet these new data demands efficiently. If not, this will limit Volvo Car's ability to reorganize itself to become a more agile electric car manufacturer.

At the Final Assembly department at Volvo Cars in Torslanda, manufacturing engineers (ME) are working together in the preparation process to translate information about the product design to process instructions for the operators. The preparation process for the engineers entails combining different requirements from R&D, ergonomics, regulation, and legal demands with an end result of an instruction document called Process & Inspection Instruction (PII). The PIIs' contain important information that is required for assembling cars in a quality-assured and correct manner, for example, operation methods, operation time settings, article numbers, and quality controls.

The process of creating and adjusting PIIs' today is rather inefficient, hours of work are being spent on unnecessary tedious steps and waiting for the Product Lifecycle Management (PLM) program to respond. The inefficiency causes frustration and MEs' feel like they are not in control when handling the PIIs'. According to Berlin & Adams (2017), this tends to lead to negative psychosocial factors such as a decrease in work motivation and passiveness. Moreover, there is an unclarity of what information in the PII is value-adding or not for the factory. Subsequently, causing quality variance due to lack of or inaccurate documented information, resulting in hours spent on rework and conflicts within the organization. The current inefficient process hinders the engineers' work with quality assurance processes, such as verification and validation, which are often postponed due to the time spent creating and updating the PIIs'. Volvo Cars are losing both valuable competency and capital when MEs' are idling and reworking.

1.3 Purpose and research questions

This thesis's purpose is to understand what inefficiencies occur, and where in the administrative process of creating assemble & control instructions and to investigate how the inefficiencies could be reduced, thus improving the work process flow to become more efficient and quality-assured.

The objective is to conduct a pre-study at the Final Assembly division at Volvo Cars, providing information regarding inefficiencies in their current work processes connected to the MEs' work on PIIs', see Figure 1.1. Furthermore, finding opportunities for improvements and giving suggestions on how to create a more efficient process flow.

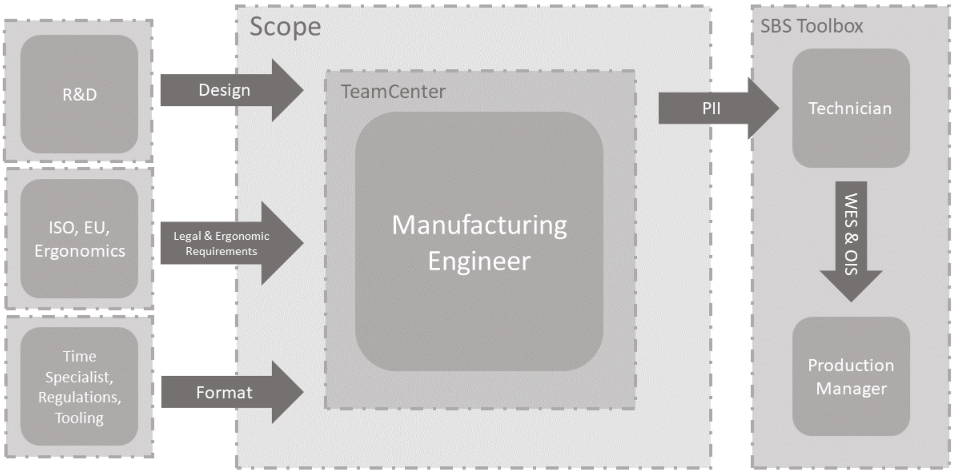

Figure 1.1: Visualization of scope, input-, and output actors for MEs' when working with PII.

This thesis will answer the following research questions constructed with the purpose of the thesis in mind to reach a conclusion addressing the process problem Volvo Cars is currently facing.

Research question 1: What inefficiencies can be identified & where in the administration of Process & Inspection Instructions?

Research question 2: How can the administration of Process & Inspection Instructions be improved to address existing inefficiencies?

1.4 Delimitations

This thesis is based on a case study performed at the Final Assembly department at Volvo Cars Torslanda, analyzing the work of Manufacturing engineers and their connected stakeholders. The focus is on identifying inefficiencies in the early development phase of creating assemble and control instructions for cars, i.e. when the concept and many of the requirements for the car are determined and the creation of the instruction document takes place. The theoretical framework of the study is based on the Lean principles, and mainly on the adaptation towards administration processes. The identified inefficiencies in the study are those that can be observed when the ME creates the instruction document and through interviews focusing on questions regarding the work process, information flow, and necessary data. The results from the current state analysis provide a basis for developing hypothetical suggestions for improvements, which is done in collaboration with the employees at Volvo Cars.

2
Methodology

This chapter describes the research methodology and research process of gathering and analyzing required data to achieve well-structured and dependable conclusions. A description of how the research quality of this thesis was assessed and some ethical considerations are presented in this chapter as well.

2.1 Research design

Bell et al. (2022) describes that a case study often is used when the aim is an in-depth explanation and the study is concerned with the uniqueness of the setting. Furthermore, methods such as observation and unstructured interviews are often used to perform such thorough examination (Bell et al. 2022). Since the thesis aimed to identify inefficiencies and possible improvements in the administration process of creating production instructions, a single-case study was suitable in that it allows for a thorough investigation of a particular setting. Due to the research area of Lean in administration processes being rather unexplored, a case study is considered appropriate for its exploration aspects and holistic perspective. The findings of the case study can therefore reveal the significance and need for further investigation on the researched topic.

Furthermore, various data-gathering methods are used to gain a broader understanding of the subject. According to Denscombe (2017) and Bell et al. (2022), using multiple methods, triangulation, increases the accuracy and reliability of the findings. Therefore, the thesis used qualitative and quantitative data-gathering methods and a literature study to get a deep understanding and a wide set of data. However, the nature of the study is qualitative and employs inductive reasoning. Bell et al. (2022) describes qualitative research as more concerned about words than numbers, a view of generating theory out of research, and seeking to understand the social reality in a setting with the mindset that people are active creators rather than passive. Therefore, with the purpose to develop an understanding of a particular setting and generate conclusions based on observations and interviews a qualitative study approach is appropriate.

To attain the thesis research questions, a methodology was selected to be used throughout the project to support a systematic process. The selected research process was the Design Research Methodology (DRM) proposed by Blessing & Chakrabarti (2009). The methodology was chosen because of the provided support with systematic planning of the research and support in selecting and reflecting upon research methods to address the research questions. Blessing & Chakrabarti (2009) describes that a methodology can support the research process and thus increase the chances of acquiring valid and useful results. The results may also be more accurate and reliable. However, the outcome can not be guaranteed due to the researchers' personal factors causing the research process to become unique.

2.1.1 Design Research Methodology

Design in the context of DRM is the entire process from identifying a need to fulfilling that need, it is a dynamic and complex process that involves people, knowledge, processes, methods, and tools (Blessing & Chakrabarti 2009). Furthermore, design research aims at understanding and improving the design. Improving the design requires a model of the existing situation, a vision of a desired situation, and lastly a vision of how to move from the existing situation to the desired one and maintain it (Blessing & Chakrabarti 2009).

DRM consists of four stages, see Figure 2.1 for a simplified illustration. Blessing & Chakrabarti (2009) emphasizes that DRM should not be executed in a linear and rigid way, it is a process with many iterations and parallel execution of stages to increase the understanding in an efficient way.

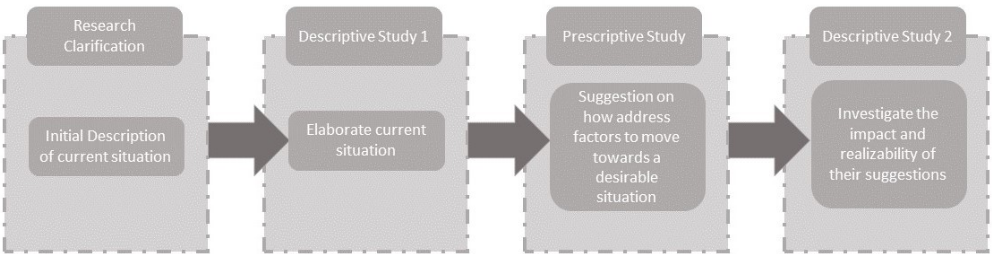

Figure 2.1: Overview of the DRM Process (Adapted from Blessing & Chakrabarti 2009)

In the first stage, Research Clarification (RC), an initial understanding and description of the research area is developed (Blessing & Chakrabarti 2009). The following stage, Descriptive Study I (DS I), is a continuation of the previous stage where the researchers elaborate on the description of the current situation, making it more detailed (Blessing & Chakrabarti 2009). In the next step, Prescriptive Study (PS), the previously attained understanding from RC and DS I is used to finding suggestions on how to move towards a more desirable situation (Blessing & Chakrabarti 2009). The last stage, Descriptive Study II (DS II), is described by Blessing & Chakrabarti (2009) as where the researchers investigate their solutions based on impact and ability to realize the desired situation.

Research Clarification (RC)
Blessing & Chakrabarti (2009) describes that the aim of RC is to identify and refine

a research problem that is both worthwhile and realistic. Finding support for the researchers' assumptions is achieved by gathering the available understanding of the research area, making it possible to create an overall research plan that is suitable to solve the issue. The main source of information is gathered through reviewing literature (Blessing & Chakrabarti 2009).

Descriptive Study I (DS I)
The aim of the DS I stage is to develop a better understanding of the current situation through reviewing and performing empirical research and reasoning (Blessing & Chakrabarti 2009). With the elaborated understanding, success factors that justify the research and its relevance can be pinpointed. Furthermore, suggestions of key factors that have the potential to improve the current situation can be identified.

Prescriptive Study (PS)
With the gathered knowledge from the previous steps, the most suitable key factors can be decided and a detailed description of the desired and improved situation can be developed (Blessing & Chakrabarti 2009). Description of solutions that address the key factors can then be developed, the solutions should be mature enough to enable evaluation of their effects with regards to the success factors.

Descriptive Study II (DS II)
Blessing & Chakrabarti (2009) describes that the main part of the last stage focuses on evaluating the developed solutions with further empirical studies. The solution is evaluated based on whether or not it can contribute to the success and deliver the expected effect. If it does not contribute to the desired effect, further improvements can be identified.

2.2 Research process

A well-structured methodology process is essential to efficiently reach the point where the presented research questions can be answered confidently. Blessing & Chakrabarti (2009) identifies seven types of research within DRM and the stages can focus on either review-based, comprehensive, or initial studies, an short overview of the different types is given in Appendix A. Review-based studies are only based on literature, comprehensive studies are based on both literature and empirical studies, and initial studies involve the first few steps to show the consequences of the results and prepare the result for further development by others.

Based on this thesis's scope, the design research type 2 is chosen. It contains a review-based RC, comprehensive DS I, and initial PS. In the initial PS stage, a concept for a solution is developed to illustrate how the findings from the previous steps can improve the current situation. The concept should be seen as a recommendation, which can be further developed to the extent that it enables evaluation of its effects. This project breaks up the research process into two phases based on the two research questions, see Figure 2.2 & 2.3. Phase 1 consists of RC and DS I and Phase 2 consists of DS I and an initial PS stage.

In the RC stage at Phase 1, the literature study and exploration empirical study of the current state were performed. The gained understanding mainly framed the scope of the research, the background, the methodology, and the theoretical framework. The next stage in Phase 1, DS I, consisted of gathering more detailed empirical data from observations and semi-structured interviews to deepen the knowledge of the current state and answer the first research question.

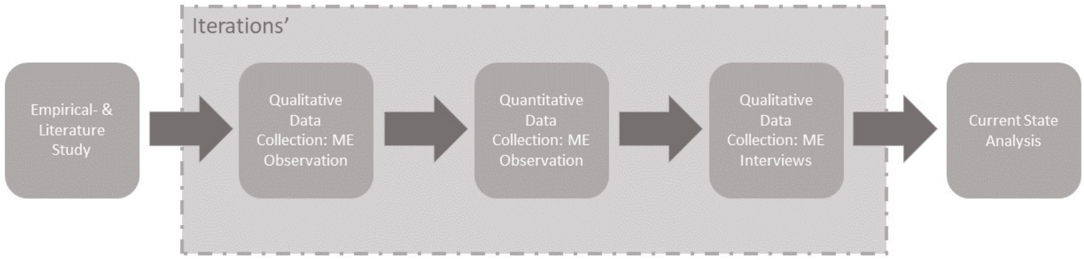

Figure 2.2: Phase 1 - Method of Current state analysis

In Phase 2, the DS I stage, the empirical study broadened to other stakeholders, which widened the understanding of the current state. The gathered data were analyzed to identify key factors that could result in improvements. At the PS initial stage, concepts for solutions were developed based on previous findings and in a cross-functional workshop with several stakeholders, answering the second research question. Lastly, the work method was applied in one more area to test and validate the process.

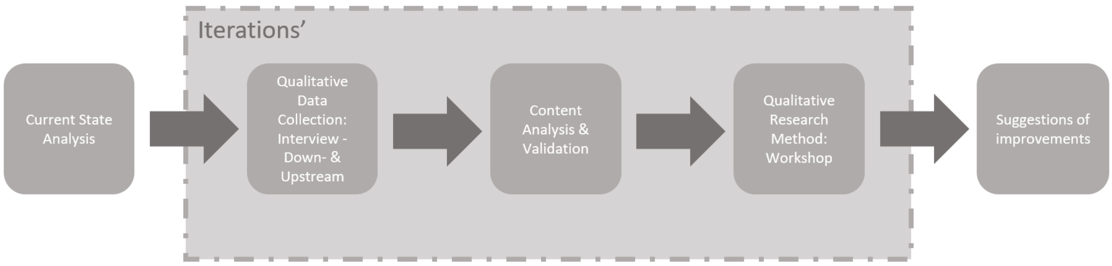

Figure 2.3: Phase 2 - Method of identification of improvement areas

2.2.1 Ethical considerations

In parallel with the two phases, a thorough stakeholder analysis was conducted to ensure that the conclusions were as objective as possible. The project had many data inputs from different parts of the organization with varied power, legitimacy, and urgency (Buch & Damle 2019). For that reason, the project was taking into consideration that study participants may have their own agendas and interests to influence the conclusions and suggestions of the project for their own personal gain. Therefore, the acquired data were validated by critically analyzing it through the created stakeholder analysis, and compared with other subjects' data in the respective and different departments.

Bell et al. (2022) describes four ethical principles which often is discussed in business research: Avoidance of harm, informed consent, privacy, and preventing deception. When planning and conducting the research, the principles were taken into consideration. All of the participants were informed of the aim of the thesis and an interview template was sent out before the interviews to allow the participants to make informed consent and prevent deception. The participants in the study were informed about the participation being anonymous and were asked for recording consent, preventing harm, and protecting their privacy.

2.3 Data collection

This section describes the various data-gathering methods and analyzing tools used to reach the presented findings.

2.3.1 Literature study

The Literature study was a recurrent activity during the entire length of the project. The study made it possible to gain initial knowledge about the area of interest and an understanding of to what extent the subject was explored in terms of verified research literature. The aim was to facilitate accessible learning, removing the need of discovering already existing knowledge. This part of the methodology is mainly connected to the first step of DRM, the Research Clarification. Searching for available information and creating the overall research plan.

The systematic literature reviews were carried out on the following databases: *Chalmers Library (provided by EBSCO) and Google Scholar*. To discover relevant literature, for this project, keywords connected to the purpose and objective were used to limit the search reach. The keywords were used in combination to find articles and books where all of them existed simultaneously and individually. The following keywords were used: *Lean administration, Lean management, Automotive industry, Car industry, Process planning, Administration processes, Product Lifecycle Management, Revision control system, Digitalization.*

2.3.2 Case study

A case study was executed to get an understanding of the present situation of handling PIIs'. This was done by studying and analyzing internal sources, e.g. PII regulations documents provided by Volvo Cars, in combination with interviews, and observations. The case study resulted in initial knowledge about the project and identification of possible stakeholders, covering the stages RC and DS I by achieving research clarification.

2.3.2.1 Observation

The observation study was split into two parts; Qualitative data collection and Quantitative data collection.

Firstly, the qualitative data collection of observation consisted of attending regular weekly meetings, where the subject around the area of interest was discussed, and shadowing MEs' when creating and adjusting PIIs'. The idea was to create an initial understanding of the work process of MEs' when handling PIIs' and possibly detect early problematic areas (Blessing & Chakrabarti 2009).

Secondly, The quantitative data collection of observation, which was executed after the qualitative data collection, consisted of screen recordings and analysis sessions in the process of creating generic standardized PIIs'. The sample group, that was observed and analyzed, had different experience levels with the creation of PIIs' and was instructed to create similar PIIs' with the same input data. The MEs' created and adjusted the PIIs' in three different stages considering internal PII milestones. The breakdown of the PII creation process, with different levels of experience, was intended to give valuable data points that will be further analyzed, and possibly result in the direct detection of waste in the current creation process.

2.3.2.2 Interviews

In the initial phase of the study, several unstructured interviews were conducted to create an understanding of the MEs' work process, terminology, and cross-functionality. Some further unstructured interviews were conducted throughout the study when there was a need to elaborate more on the understanding and clarify the gained knowledge.

For the succeeding part of the study, the purpose of the interviews was to validate the gathered data from the Observation process. Furthermore, explore problematic areas through MEs' individual experience when working with PIIs' and identify common limitations. This was done simultaneously with gathering information about the input and output actors involved, as well as identifying the PII's current information requirements, desired information to exist, and unnecessary information.

The interviews were conducted in a semi-constructed, deductive, and open-ended structure, the interview templates can be seen in Appendix C. The interview structure gave the MEs', and other actors, the space to elaborate their view on the problematic areas, common individual waste, and limitations of current systems & operations. All this and at the same time not going off track with the scope of the project in mind (Patel & Davidson 2019). This approach gave the necessary information to further identify and structure areas of possible improvements. With consent from the participants, the interviews were recorded and transcribed. For further content analysis and documentation.

The selection of participants for the study was based on recommendations of relevant and available employees from the supervisors at Volvo Cars followed by snowball sampling. Snowball sampling is a method to identify new potential participants through participant recommendations (Bell et al. 2022). Of the total 18 participants, including the two supervisors, ten were chosen from recommendations and six were chosen from snowball sampling. Furthermore, the participants had to fulfill some requirements to filter out converge that are uncalled for, e.g. results that do not represent their department as a whole. The requirements were:

- All ME interviewees must either currently be involved in PII creation or have had experience in PII creation within the past year.
- All output interviewees shall have direct contact with PIIs'.
- All input interviewees shall be in frequent contact with MEs' working with PIIs'.

In Table 2.1, a detailed overview of the participants in the study is given. The table includes the participant's position, department, and years of experience in their position. Followed by the type of participation in the study e.g. participation in the workshop or observation.

Table 2.1: Table of participants in the study. Type: UI - unstructured interview, SI - structured interview, W - workshop, O - observation

Participant	Experience in the position	Position	Department	Type
M1	5 years	Manufacturing Engineer (Vehicle and motion climate)	Manufacturing	UI, SI, O
M2	2 years	Manufacturing Engineer (Interior)	Manufacturing	UI, SI, O
M3	7 years	Manufacturing Engineer (Interior)	Manufacturing	SI, O
M4	2 years	Manufacturing Engineer (Vehicle and motion climate)	Manufacturing	SI, W
M5	4 years	Manufacturing Engineer (Electrical)	Manufacturing	UI, O
M6	19 years	Process Manager Operational Development	Manufacturing	UI, SI
M7	10 years	PLM Manager	Manufacturing	UI, W
M8	3 years	Head of Business Development	Manufacturing	UI, W
M9	1 year	Business Process Leader	Manufacturing	UI, W
M10	25 years	Time Specialist	Manufacturing	UI, O
P1	3 years	Efficiency coordinator and Business application owner for SBS toolbox	Plant	SI, W
P2	6 years	Process Technician	Plant	SI
P3	11 years	Global Launch Specialist	Plant	SI
P4	13 years	Global Launch Specialist	Plant	SI
R1	6 years	Global Lead Engineer (Break and Steering)	Research & Development	SI, W
I1	7 years	Business Analyst	IT	UI
I2	8 years	Business Analyst	IT	UI
I3	20 years	Product Owner	IT	UI

2.3.2.3 Workshop

The workshop aimed to generate suggestions for enhancing efficiency and promoting collaboration by identifying areas of improvement. Specifically, the workshop focused on the initial phase of the PS stage, where participants provided input to develop recommendations for enhancing the current situation. The workshop was led by researchers who presented pre-structured cases, carefully selected through content analysis, for participants to collaboratively solve (Blessing & Chakrabarti 2009). As such, the session was designed as a learning activity for all attendees.

The session was conducted at the end of the project when all information from the interviews and observations was collected and analyzed. It took place at the Volvo Cars office, with six participants from Volvo Cars and the two researchers. The session was divided into three parts, each with one case to discuss for about 25 min.

The workshop was conducted with different areas of interest where at least one representative of the different departments was present. The conclusions and procedures of the workshop were continuously documented throughout the event, removing the risk of forgetting valuable inputs. Before each case discussion, the participants were provided materials to jot down their initial thoughts and suggestions for improvements. The written materials were gathered at the session's conclusion for additional analysis. Additionally, with the participant's consent, the session was recorded for further examination.

2.4 Data analysis

This section describes how the gathered data were re-structured and analyzed.

2.4.1 Value stream mapping

Value Stream Mapping (VSM) is essential for identifying, analyzing, and revealing potential improvement areas in the current state workflow of creating PIIs'. The character of the current state of the creation process is heavily software based with digital information flows. Therefore, the structure of the VSM was adapted to a DevOps-model (Tankhiwale & Saraf 2020).

The end goal of a VSM is to improve the understanding by visualization of the information flow of a process chain and possibly pinpoint where inefficiency exists in the form of waste. Therefore, the recorded process times were evaluated in terms of if they bring any value to the end customers, in this case, the plant. The evaluation of whether a process was considered to be valuable or wasteful was based on reasoning with Lean administration principles as theoretical ground.

2.4.2 Coding and thematic analysis

In coding the qualitative data, thematic analysis was used. Thematic trajectory analysis is an iterative process of breaking down gathered transcripts, e.g. from interviews and workshops, in a way where common themes, codes, and patterns can be identified (Spencer et al. 2021). With the initially gathered information, the qualitative data were evaluated and revised against each other to ensure the viability of the statements. When no contradiction of the data can be identified, the verified themes and codes can be combined to create a narrative.

The reasoning behind the thematic analysis was based on the Lean administration principles and the description of wasteful activities. The semi-structured interviews and workshop were analyzed in the same manner, important information in the data was highlighted and labeled with codes. Important information was considered to be information that could contribute to answering the research questions, increase the understanding of the current situation, and that verified information through triangulation. Thereafter, common themes were identified among the highlighted parts and combined into thematic narratives. Five themes were identified in interviews with Manufacturing Engineers, three themes were found in interviews with the Plant, and two themes were found in interviews with R&D. For the workshop, the narratives were categorized by the cases.

2.4.3 Stakeholder analysis

Cadle et al. (2014) describes that a significant part of business analysis is collaborating with stakeholders. The stakeholders possess the knowledge that the researchers need to obtain and the ability to support or obstruct changes. Cadle et al. (2014) explains the importance of analyzing the gathered information together with the perspectives of the provider to enable the researchers to uncover hidden agendas and personal priorities. Conflicts and failure of creating new processes can transpire if the stakeholders are not taken into consideration (Cadle et al. 2014).

The applied approach for the stakeholder analysis was inspired by the influence/interest grid and persona techniques, analyzing important factors which may influence the collected data. Cadle et al. (2014) describes the persona technique to be a generalized representation of a stakeholder i.e., a persona, with developed descriptions of their goals and values. Furthermore, the influence/interest grid is a technique to rank the different stakeholders depending on their influence and interest in a project (Cadle et al. 2014). For this thesis, possible expectations and agendas were described for the generalized stakeholder.

Identifying stakeholders and analyzing their potential interest and influence over the project was important to ensure that the collected data could be analyzed objectively. All the participants' departments were identified as stakeholders who have both interest and influence over the project. The researchers ranked the stakeholders on a scale of low, medium, or high on both of the parameters which were based on their ability to change the outcome of the study and on how the report may affect them.

Descriptions of what the stakeholders may expect from the project and possible agendas which may influence the information given by the stakeholders were developed by the researchers and later confirmed with the stakeholders to allow for transparency. The stakeholder analysis was used throughout the data collection and analysis to ensure the objectivity and truthiness of the data.

2.5 Research Quality

When evaluating the quality of business research, the three criteria, Validity, Reliability, and Objectiveness is commonly used, however, it is mentioned that the criteria are mainly relevant for quantitative research (Bell et al. 2022). When assessing the research quality of qualitative research, Lincoln & Guba (1985) proposes that the criteria authenticity and trustworthiness are better suited. Furthermore, trustworthiness is divided into four sub-criteria: Credibility, Transferability, Dependability, and Conformability. Therefore, to ensure the research quality of this thesis, the criteria proposed by Lincoln & Guba (1985) were assessed throughout the project.

2.5.1 Authenticity

The authenticity criteria refer to the degree of representation of different viewpoints and values from participants in the study which enables a better understanding of the situations (Bell et al. 2022).

To guarantee the authenticity of the research, multiple interviews have been conducted with several employees in the same position to ensure that multiple perspectives have been covered. Furthermore, employees at different departments that are connected to the PII process have been interviewed to widen their understanding of the whole process and present a broad view of realities. To achieve an objective balance of the participants' perspectives, a stakeholder analysis was conducted to create an understanding of the participants' interests in the project and critically compare the responses.

2.5.2 Credibility

Credibility in qualitative research refers to the accuracy and truth of the research findings (Bell et al. 2022). Thus, credible research entails that the findings are plausible and that the information is correctly interpreted. According to Denscombe (2017) and Bell et al. (2022), using multiple methods, triangulation, to cross-check qualitative data can ensure credibility.

The thesis applied triangulation, using several data collection methods and collecting data from different information sources to strengthen the credibility of the findings. Furthermore, presentations of the findings for the participants were continuously held throughout the project, allowing the participants to discover and correct possible misinterpretations. The workshop also established credibility, providing further opportunities for discussions of the findings and their accuracy.

2.5.3 Transferability

The quality criteria Transferability concerns the degree of transferability of the results to other contexts and settings (Bell et al. 2022). Lincoln & Guba (1985) explains that the researchers' task is not to prove that the data could be transferred to other cases, but rather to provide a thick description of the data to enable others to make the judgment if the research is applicable in other contexts.

Thorough efforts have been on providing a thick description to enable the transferability of the research. The thesis includes detailed descriptions of the particular situation at Volvo Cars, the collected data, and the participants. Furthermore, the methods and procedures that have been used in the project are thoroughly described. Thus, the research procedure is transferable and could be applied by others in their settings, to reach their own unique results.

2.5.4 Dependability

Dependability is the corresponding criterion for reliability, i.e., to which degree the results can be replicated in a similar setting (Bell et al. 2022). It can be ensured by keeping complete records of all the phases in the research process to allow for an auditing approach, however, due to it being a highly demanding process with large datasets it has not become a popular approach (Bell et al. 2022).

As mentioned, the thesis describes the applied methods and procedures for collecting and analyzing data in detail, allowing the study to be replicated theoretically. The interview guides are provided in the thesis to ensure further replication possibilities of the research. Moreover, the work method was applied in a second case at Volvo Cars, ensuring method validity.

2.5.5 Confirmability

Confirmability is concerned with the objectivity of the research. Bell et al. (2022) describes that complete objectivity is impossible in business research but it should be clear that the researcher has not allowed their personal values to overly manifest the research process nor the findings from the research.

The objectiveness of this thesis was attained through the triangulation of information and sources to deepen the researchers' understanding and thus increase the probability that personal interest did not affect the data and the interpretations. Furthermore, the researchers individually analyzed and interpreted the collected data and then compared the results to reduce the risk of bias. Moreover, the data were critically analyzed with the stakeholder analysis in mind, increasing the confirmability of the collected data.

3

Theoretical framework

This section presents the theoretical framework used in this study to establish a research basis for the obtained results. The following topics will be described in this section: Lean Production (with a main focus on Lean Administration), Value Stream Mapping, Product Lifecycle Management, Digitalization, and Stakeholder Analysis. The topics are chosen based on their relevance in providing knowledge on identifying inefficiencies, information on areas within administration processes, and the knowledge basis for stakeholder analysis.

3.1 Lean production

Lean production originates from the Toyota Production System (TPS) in the 20th century and was developed to improve quality and productivity through the identification and removal of deficiency and wastes in the production system (Holweg et al. 2018). The definition of waste is any activity that does not contribute to value creation and value is derived from the perspective of what the customers need and what they are willing to pay for (Hines et al. 2004). Therefore, wasteful activities, also called non-value adding activities, are considered unnecessary as they do not benefit the customer and should thus be eliminated.

There are three types of wasteful activities (Muri, Mura, Muda) that were identified in TPS, the philosophy is based on the identification and removal of these activities, resulting in increased efficiency of processes (Eaton 2013). Muri, often described as overburden in English, is regarding too high of a workload on machines and people (Eaton 2013). It is further described that it can be avoided through evenly distributed work and standardization, allowing sufficient, but not too much, time to perform a task. As a consequence of Muri, workers who are exposed to overburdening physical and mental capacity can experience lower motivation, mental stress, and mistakes can occur more frequently (Umar et al. 2023). Mura, often referred to as unevenness in English, is about inconsistency and variability in processes, often seen as a cause for Muda (Eaton 2013). For example, inconsistency can cause waiting times and overproduction. Muda, generally described as waste, is regarding non-value-adding activities (Eaton 2013). It is any activity that consumes resources without contributing value for the customers, however, there are two types of mudas (Eaton 2013). Both types are non-value adding activities, however, type one is necessary for the customer and cannot be eliminated directly and type two is unnecessary and thus can be removed immediately. Originally, seven types of Mudas were identified in TPS, some have later added and acknowledged an eighth Muda (Eaton 2013). The eight wastes are: Transportation, inventory, motion, waiting, overproduction, processing, rework, and talent (Eaton 2013).

Although Lean production originally was developed for and by the car manufacturer Toyota, the philosophy has spread to many different industries such as health care- and government processes (Larsson et al. 2008, Brännmark 2011). It has been acknowledged that the Lean philosophy has the potential to be successfully implemented in areas such as product development and administrative processes if the uniqueness of the area is respected (Direction 2005).

3.1.1 Lean administration

In the following subsection, a description of Lean administration and the concepts will be presented as it is the main focus of this thesis to improve the efficiency of administration processes.

As previously mentioned, Lean has spread beyond the car manufacturing processes and into other industries and areas while keeping the core concept of Lean, streamlining and eliminating waste to achieve improved performance and economic gains (Direction 2005). Practitioners have made adoptions of Lean to better suit the administration area and their terminology and processes, respecting the uniqueness of the area as Direction (2005) described to be important for successfully implementing Lean into other contexts. The phrasing Lean Administration exists in videos, courses and explanations when searched on the web, however, literature and research regarding the subject of Lean Administration are more scarce. Larsson et al. (2008) noticed the absence of literature and took it upon himself to write the book ”Lean Administration” which will be used as the source for the literature review on Lean administration.

Larsson et al. (2008) expresses that Lean are not limited to creating a culture of continuous improvements in companies' manufacturing systems. With a great advantage, the philosophy, methodology, and tools can be applied in administration support processes. Furthermore, the thinking regarding removing wasteful activities is also applicable in this area.

Larsson et al. (2008) have the same belief as Eaton (2013) regarding the existence of two different types of non-value added activities. Larsson et al. (2008) describes that necessary non-value added activities should be minimized, which could be done by remaking the shape of the value-added activity. Some mentioned examples of necessary non-value added activities are those caused by law, environmental, or moral reasons. Furthermore, the non-value added activities are tasks that do not contribute at all to the value-added activities. A few examples are double quality controls, correction of data, and double work.

Two pre-condition for succeeding with Lean Administration is described by Larsson et al. (2008). Firstly, by understanding the dependencies between functions and teams, an internal customer can depend on others' performance to perform their work. Secondly, to see the agreed-upon requirements, not as quality goals but rather as a starting point for further improvements.

The concept of Lean Administration does not significantly differ from Lean Production, however, Larsson et al. (2008) describes that the concept has to be interpreted through an administrative perspective to make use of the concept. Larsson et al. (2008) have interpreted the 14 management principles of Lean to better suit the administration area, see Appendix B for a summarized version. Some principles are more relevant than others when analyzing the administrative processes, Larsson et al. (2008) consider that principles 2-8 are directly related to the support processes while the other principles are more connected to building a strong and long-term culture. Therefore, for this thesis with the focus of analyzing the administrative support processes, principles 2-8 will be the most relevant and of focus and thus a shorter description of the used principles will be presented below.

- **Principle 2.** Create a continuous flow in the administration support process.
- **Principle 3.** Only produce when and what the customer need.
- **Principle 4.** Level out the workload.
- **Principle 5.** Create an administration culture based on that it should be easy to make right and difficult to make errors.
- **Principle 6.** Standardize and stabilize.
- **Principle 7.** Visualize the process so that no problems are hidden.
- **Principle 8.** Use technology to support the administration processes when the process has been simplified.

Larsson et al. (2008) describes that different kinds of waste caused by information management can be found by searching for repetition and deficiency in the administrative processes, cross-functional work, documents, and data. To systematically analyze and find unnecessary work in the administrative support processes, Larsson et al. (2008) identified eight areas where waste often occurs. The eight areas have a strong connection to the eight mudas described in Lean Production but they have been slightly adapted to better suit administration processes. To understand how the mudas are adapted and interpreted from an administrative perspective, a shorter description provided by Larsson et al. (2008) of the wastes is presented below.

1. **Overproduction:** Producing more than the customer needs creates extra administrative work which is not in balance with the demand.
2. **Waiting times:** Administrative processes can be in a waiting stage similar to products in work. Finalizing the processes eliminates the waiting times.
3. **Unnecessary motions:** Placing aids for the administrative support processes closer to each other reduces motions. Bad ergonomics can decrease quality and well-being.
4. **Incorrect processes:** Administrative processes which do not fulfill the customers' demands often result in unnecessary checks and double work.

5. **Producing faulty services:** Faulty services causes rework, delays, and increases the company's costs. Furthermore, it creates dissatisfied customers.
6. **Badly integrated systems:** Manually transferring information from one system to another can be eliminated by having an integrated IT system which increases information management efficiency.
7. **Searching for information and data:** Unnecessary searching can be eliminated by having things in order at the joint servers and their own hard drives.
8. **Underutilized creativity:** Not utilizing the knowledge and ideas that exist within the administrative support processes is considered to be wasteful.

3.2 Value Stream Mapping

According to Fukuzawa (2020), Value stream mapping originates from the Toyota Production System (TPS) and is a tool enterprises can use to visualize and analyze their current material and information flow. This is usually done by a cross-functional team of experts in their corresponding area to engage their organization's journey to lean manufacturing. Value stream mapping is mostly used and known in physical production-based scenarios where raw material, suppliers, and production balancing is major factors in the execution. See Figure 3.1

As previously stated, Value stream mapping involves mapping the current flow of materials, from raw materials to the end products, as well as the information flow and interaction between the processes. The end goal of the mapping is to create an overview of the entire material and information flow to identify waste and inefficiencies. The organization can then use this model and extract information where improvement potentials exist. The organization can then reconstruct its current material and information flow to improve its efficiency, e.g. reducing costs and increasing customer value from a manufacturing perspective (Fukuzawa 2020).

Mapping usually consists of identifying *Lead times*, *Process times*, and *Percent of accuracy* (Process rejection rate, e.g. rework, etc) Tiwari & Sharma (2022).

The mapping of waste is recommended to be viewed from the perspective of the end-customer. According to Larsson et al. (2008), the value and waste can be more smoothly distinguished this way. This involves examining the entire value chain of a product or service and identifying processes or activities that do not add value to the end-customer. The end-customer can both be external (e.g. customers of the product or process) and internal (e.g. stakeholders and other departments within the company).

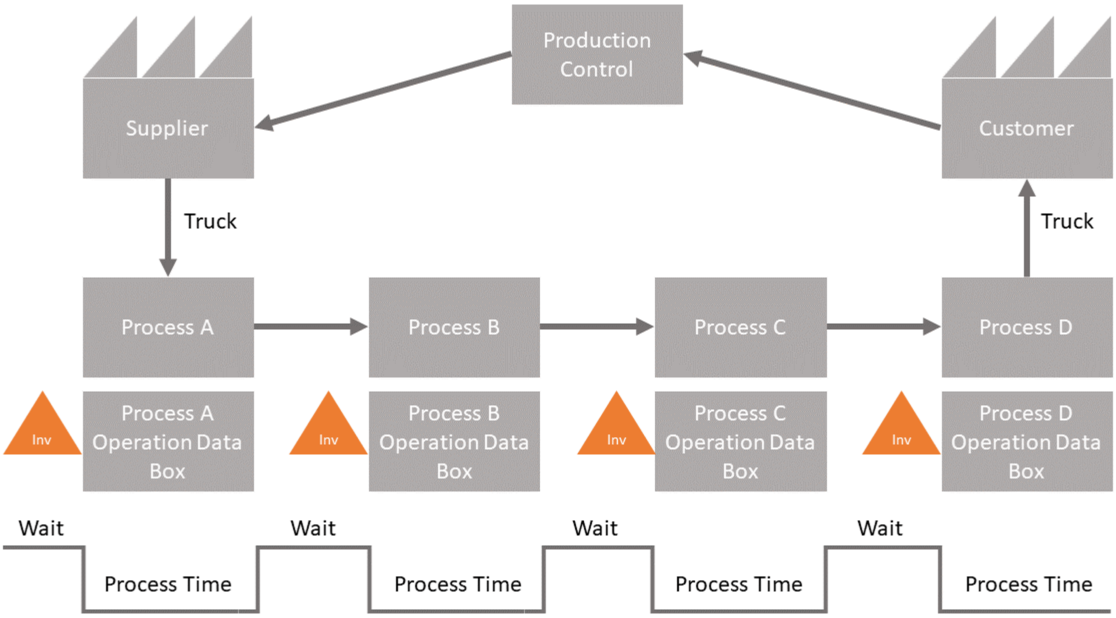

Figure 3.1: Basic illustration of a Value Stream mapping

3.2.1 Value Stream Mapping in a DevOps process perspective

According to Tankhiwale & Saraf (2020), Value Stream mapping can also be used in a software-based environment. From this perspective, the value stream is represented through software delivery processes, from initial software requests to deployment. See Figure 3.2. The key stages of the development process need to be identified and thoroughly analyzed. The results of this shall gain insights into how continuous stream improvement can be acquired. The main goal of continuous improvements is to reduce lead times and increase the quality of the software releases. This ultimately will create more value for the end customers.

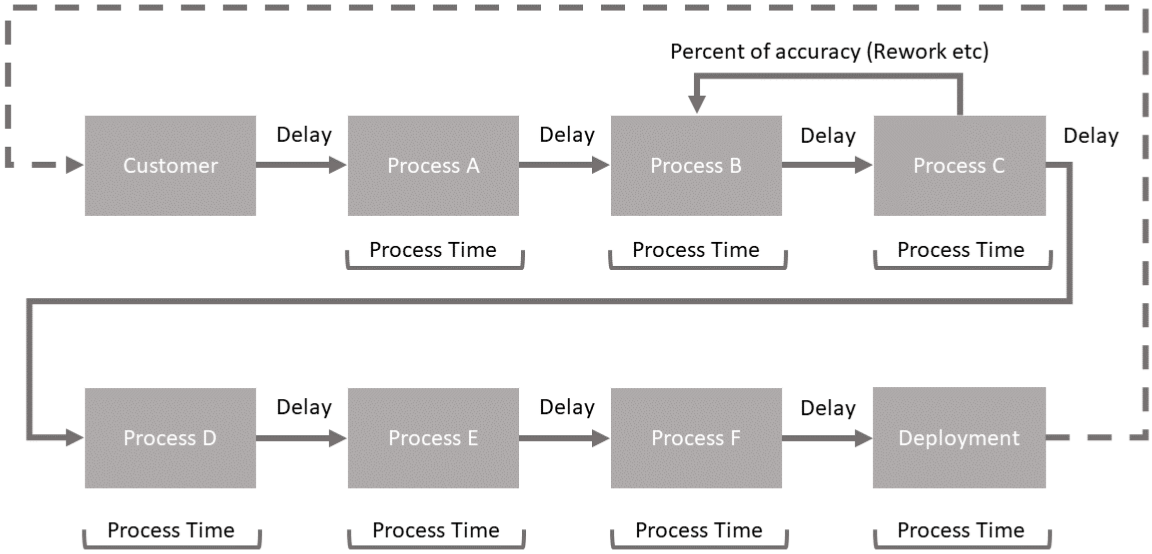

Figure 3.2: Basic illustration of a Value Stream mapping in a DevOps process perspective

3.3 Product Lifecycle Management

Product Lifecycle Management (PLM) is a systematic process for developing and managing products and all the related information to the product (Saaksvuori & Immonen 2008, Stark & Stark 2020). In this context, Saaksvuori & Immonen (2008) describes a product to not only be a physical and tangible product but also include services and intangible products such as software in the definition. PLM covers a holistic perspective of a product's whole lifecycle, from idea to disposal, and includes information such as BOM, quality standards, manufacturing procedures, and change orders (Saaksvuori & Immonen 2008).

There exists several PLM software on the market which aid the PLM process of managing data and providing access to documents across the organization. Some examples of companies that provide PLM systems in the market are Siemens, PTC, Oracle, and Dassault Group (Aram & Eastman 2013).

3.3.1 Traceability

Product traceability has increasingly become a demand from both consumers and regulators in industries such as pharmaceutical and automotive to provide and assure security (Stark & Stark 2020). If an organization discovers issues with a batch of products, they can take advantage of the tractability and trace the faulty products, thus only recalling the products which may have the same issues (Stark &

Stark 2020). Therefore, traceability can be one of the many possible drivers for implementing a PLM system.

3.3.2 Revision control

In high-tech environments, the initial product designs frequently change throughout the development phase (Stark & Stark 2020). Assuring that the affected employees have access to the latest versions creates a big challenge for organizations when the data integrity must be maintained regardless of the situations (Saaksvuori & Immonen 2008).

Keeping an effective Product Change Control by documenting, controlling and clearly defining the changes throughout the product's lifecycle reduces the risks of employees not using the latest versions and unauthorized changes (Stark & Stark 2020). Furthermore, the traceability of changes allows the affected employees to be aware of the change and receive the newest updates. Saaksvuori & Immonen (2008) describes a possible problematic scenario when information is stored in different data media or even as paper documents in some places. Storing information in different locations can create confusion on whether or not the version is the most recent.

Saaksvuori & Immonen (2008) describes some features of PLM systems that are connected to a generic change process. When a change has been determined, the system can inform all interested parties of the change, it can also inform a person who tries to retrieve a document if the document is being updated. After all the changes have been made, the document or parts can be released, i.e. publication of the item. The system can then automatically give the item a new version number. The PLM system also has the benefit to bundle large amounts of change requests and orders to quickly gather the necessary approvals and inspections.

3.4 Digitalization

Digitalization refers to the process of converting analog processes into digital form (Ritter & Pedersen 2020). According to Ritter & Pedersen (2020), digitalization is an absolute necessity to achieve strong capability, in the current agile business environment.

The digitalization of analog processes can lead to a reduction in physical process administration and, in certain cases, result in faster process execution. By automating previously manual and time-consuming processes, digitalization enables firms to expand their service/product offerings. Consequently, it becomes crucial for organizations to digitalize key processes to enhance their competitive offerings and decrease labor costs associated with execution and administration Ritter & Pedersen (2020).

Although the digitalization of analog processes can offer benefits to business customers, it is important to note that certain digitalization initiatives can be expensive and potentially face customer rejection. Therefore, it is crucial to thoroughly assess the suitability of digitalization projects and carefully weigh the potential benefits and consequences before making any decisions. It is essential to conduct a comprehensive evaluation of how digitalization may impact the reputation of the firm and determine whether the anticipated advantages outweigh any potential drawbacks Ritter & Pedersen (2020).

According to Correani et al. (2020), to achieve successful digital transformation, organizations must thoroughly assess their existing technological capabilities and align them with strategic goals. It is imperative for the organization to clearly define its transformation objectives to establish a clear direction. Allocating resources to areas that will bring the greatest benefit in line with strategic goals is crucial. A customer-centric approach should guide the digital transformation, focusing on delivering value to end-customers and discerning what adds value and what does not.

3.4.1 Data entry errors

When entering data into the computers, accuracy often depends on the person who adds the data (Doyle 1985, Barchard & Pace 2011). Several types of errors can occur and the most effective way to eliminate them is by avoiding human handling of the data (Doyle 1985). Transcription errors occur when the raw data is written into the computer. The error includes mistakes such as misreading the raw data and entering incorrect characters (Doyle 1985). Another type of error is the transposition error, which occurs when characters are interchanged (Al-Oudat 2017).

In a study performed by Barchard & Pace (2011), 195 participants were asked to enter data in Excel from raw data sheets. They found that when single entering data i.e., without any methods for preventing errors, full accuracy was only achieved by 5.5% of the participants. The two types of methods for preventing errors were, double-entry with checking for mismatches and visual checking the input values. For the double entry, full accuracy was achieved by 77.4% of the participants and for visual checking it was 17.1%. However, the researchers concluded that visual checking was no more accurate than single entering due to not reaching statistical significance for the visual checking. The average errors for single entering data were 12 across the 1260 entries.

3.5 Stakeholder Analysis

Cadle et al. (2014) describes that the process of working with stakeholders can be divided into three steps: Stakeholder identification, stakeholder analysis, and stakeholder management. The first step is to identify those who work with or are interested in the research area. Early identification of the stakeholders can support researchers to understand the different views and thus handle differences when needed. The second step is to analyze and categorize the stakeholders depending on different factors, such as the level of influence. The analysis creates the foundation for deciding the type of management strategy. Lastly, the researchers identify and implement a management strategy that enables them to handle the different stakeholders. Additional techniques are used in this stage to support the researchers in negotiating and managing conflicts.

Three types of techniques for stakeholder identifications were described by Cadle et al. (2014). Stakeholder nomination, the project sponsor helps to identify the stakeholders. Background research, using documentation connected to the business area of interest to identify stakeholders. Stakeholder wheel, eight different groups are included in the wheel and the researchers systematically look at each group to identify stakeholders, e.g. customers and regulators are two groups.

Power/interest grid and personas are two techniques for stakeholder analysis mentioned by Cadle et al. (2014). The power/interest grid, also named the influence/interest grid, is a technique for categorizing the stakeholders depending on their influence and interest in the project. For example, a stakeholder who has high influence and power needs to be actively managed and kept informed about each step throughout the project. Personas are a representation of a group of stakeholders. The researchers consider the stakeholders' e.g. behaviors and motivations, finding patterns and construction of representative personas. A persona can be described by personal, professional, and preferences information.

Stakeholder management planning is one of the techniques mentioned by Cadle et al. (2014). The plan provides a framework for documenting the information gathered from previous steps and an assessment of which actions to take.

4

Empirical Results

In this section, the results of the case study are presented.

4.1 Stakeholder analysis

In Table 4.1 the stakeholders and their role in the project are presented along with their interest and influence in the project. The stakeholders at Volvo Cars were grouped by departments, five departments were identified to be stakeholders due to their impact and cooperation with the project. Furthermore, a sixth stakeholder was identified to be Chalmers due to the research being conducted and supervised by the university.

Table 4.1: Table of Stakeholders' Interest and Influence for the Project

Stakeholders	**Role in project**	**Interest**	**Influence**
Business development (Supervisor)	Gives input on which areas to study and supports with e.g., contacts and information	High	High
Manufacturing engineer	Supports with data regarding the work process	High	High
Plant department	Provides data regarding what is necessary information for them	High	High
IT department	Gives their professional opinion on IT-related issues	Medium	Medium
Research & Development	Provides information regarding the data that is sent to ME	Medium	Low
Chalmers (Supervisor)	Gives input on the academical part of the project	High	High

Furthermore, in Table 4.2 the stakeholders' expectations and possible agendas are presented. The expectations and possible agendas were first developed by the researchers and later checked with the stakeholders to allow for transparency and further input.

Table 4.2: Table of Stakeholders expectations and possible agendas

Stakeholders	Expectations	Possible agendas
Business development (Supervisor)	A pre-study regarding the waste in the PII administration processes. The end goal of an improved work process, using the freed-up time to ensure quality	Wants to find information regarding unnecessary work connected to the administration process of PII.
Manufacturing engineer	Expects that the project finds unnecessary steps in the process and possible solutions to improve the work process.	Wants to put as little time as possible on administration process.
Plant department	Expects that the project presents information regarding what information the plant need.	Wants to retrieve the needed information from the PIIs' as efficiently as possible.
IT department	Wants input for improvements of the PLM system	Does not want too complicated or time-consuming solutions.
Research & Development	Could expect information regarding what type and format of data ME requires.	Does not want to spend more time creating data or complex solutions.
Chalmers (Supervisor)	An academic report which contributes to research.	Wants a state-of-the-art academical report which represents Chalmers and contributes positively to its reputation.

4.2 Manufacturing engineering at Volvo Cars

The role of a Manufacturing Engineer (ME) at Volvo Cars carries a significant amount of responsibility. They are responsible for contributing to the preparation and implementation of products and manufacturing processes, ensuring that product and process solutions meet various manufacturing key attributes such as quality, line balancing, cost efficiency, environment, flexibility, and ergonomic standards. Additionally, they play an active role in developing methods and tools for the next generation of production lines and products.

Manufacturing engineers serve as a vital link in the communication between upstream R&D, downstream Plant, and mid-layer departments, such as Tooling, Ergonomics, Time Specialist, and Legal. See Figure 4.1. They are involved in every aspect of the car manufacturing process, from the initial design phases to the car's final implementation in the production lines. As a result, they have considerable influence over the car's appearance and the manufacturing sequence, which is essential in reducing potential manufacturing problems, e.g. not enough space to assemble the product or the set assembling order is wrong/not possible. The current rotation rate for MEs' is quite high. Reflecting high stress and a springboard culture for the role.

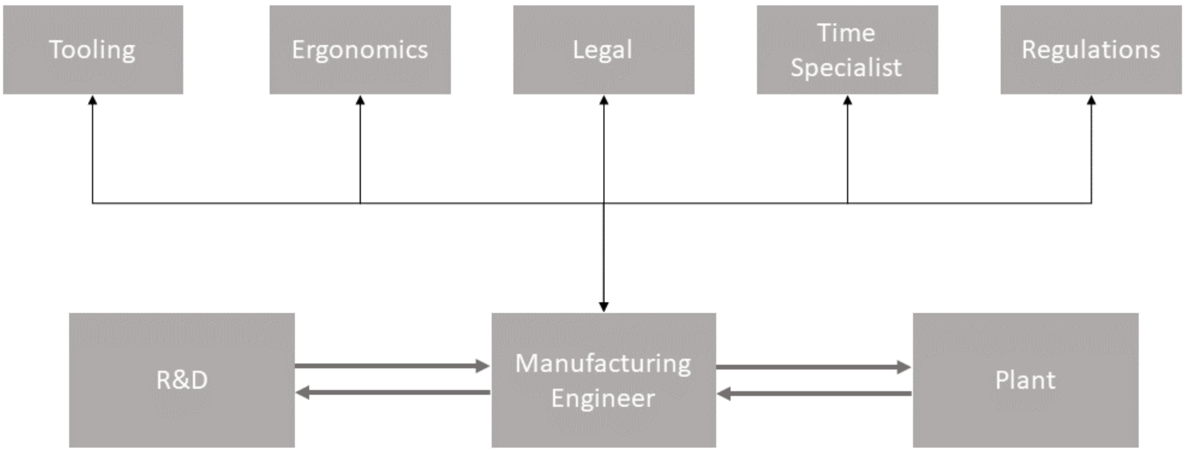

Figure 4.1: Basic illustration of communication structure in ME perspective

4.2.1 Process & Inspection Instruction

Process & Inspection Instruction (PII) is a package with instructions on how a specific product should be assembled/installed. See Appendix D. PIIs' consist of operations, structures, pictures, models, classifications, tools, and results from P-FMEA on how the assembly process should be executed and what risks exist. The order of assembling a car exists in the form of a multitude of PIIs' in a certain sequence. MEs' have ownership of different PIIs' and are in charge of that their PIIs' are possible to execute in the most efficient way possible.

As previously stated, a large part of MEs' work, besides creating and adjusting PIIs', is the creation of pictures that get attached to the PIIs'. The pictures get created by inspecting the virtual model (EBOM model). Then, take screenshots of the areas of interest as well as an "overview" picture. The pictures then get imported into Microsoft PowerPoint where the ME connects the operation numbers with the area of interest through operation-"balloons". The ME then saves the PowerPoint slides as PDF and uploads the PowerPoint and PDF files on the corresponding PII. The pictures can be of varying quality depending on the ME.

4.2.2 Workflow

The workflow for a Manufacturing Engineer (ME) involves several steps. First, they receive a Change Order (CO) from R&D (upstream) with information on updates such as new or discontinued articles, then the ME either needs to update or create a new Production Inspection Instruction (PII). The CO document outlines the changes to a product, which the ME takes into consideration and then creates the necessary changes in the internal Product Lifecycle Management (PLM) system called TeamCenter. Next, downstream Plant receives a notification of the change and determine whether it will impact the production process. These changes can be minor, such as a change in the responsible ME for the PII, or major, such as a change in structure or the creation of additional operations. Structure refers to the physical product that is to be consumed within the operation(s).

4.2.3 Milestones

The launch of a new product in the ME department involves several important milestones. Specifically, this project focuses on two critical stages: the initial phase of PII and the subsequent adjustment phase. The work process involves four critical milestones, namely V0, V1, V2, and VP, each culminating in a Virtual Build Event (VBE) to evaluate the progress achieved at that juncture. See Figure 4.2.

Failure to meet the milestone requirements results in the department's inability to proceed to the next phase. The success of the workflow is highly contingent on the performance of the R&D department. If R&D falls behind on its milestones, the ME department cannot integrate its products into the PIIs', leading to delays in delivering the final product to Plant. Therefore, modifications in the early design stage (R&D department) can significantly affect the product's introduction time on the production lines. This reliance can potentially result in a devastating ripple effect. MEs' typically work on multiple products simultaneously.

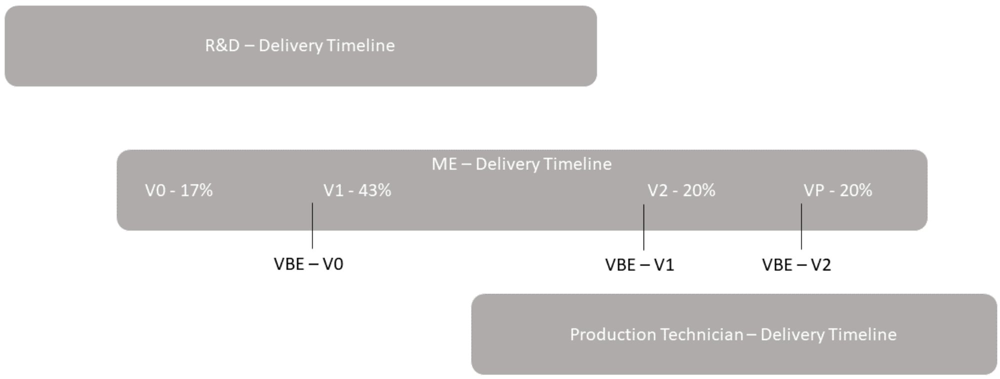

Figure 4.2: Basic illustration of Milestones and VBE

Milestone: V0
The V0 milestone is the shortest length of all milestones, about 17% of ME's work time. The PIIs' are created for the products but only a vague generic operation is implemented and a visual model (EBOM). This Milestone use is to create a bare-bones idea of how the product should be manufactured and in what order it should be assembled.

Milestone: V1
The V1 milestone is the longest length of all milestones, about 43% of ME's work time. The PIIs' from V0 get upgraded with more specific operations, corresponding structure numbers, and assigned tools needed to execute the operations in production. According to MEs' a generic PII in the V1 state has around: 7 Operations, 3 Structures, and 3 Tools.

Milestone: V2
The V2 milestone is about 20% of ME's work time. In V2 the ME adjusts the PIIs', e.g. adds additional operations if needed, and if R&D has deployed new material; changes structure numbers and visual models. The workflow resembles V1.

Milestone: VP
The VP milestone is about 20% of ME work time. It resembles the previous milestones workflow (V1 and V2) with a hefty amount of time being spent on creating process pictures.

4.3 Value Stream Mapping

The output of the quantitative data collection; Observation, consists of identified main processes, corresponding process times (PT), and in-between process lead times (ST) when creating PIIs'. There was a slight lack of data on the Percent of accuracy, therefore Percent of accuracy is combined with in-between process lead times (ST) with the precondition that R&D has released all inputs which Percent of accuracy is relenting on. This data was combined into process blocks where each activity got evaluated in what input data might be needed to perform the activity and in what software/source the ME can extract the information. This shows that a process block's process time can be influenced by upstream departments, e.g R&D.

The Quantitative data collection of "Observation" is conducted by observing four MEs' when creating PIIs' in the different degrees of maturity; V0 and V1. VSM is executed on the observations and combined into unified mean-time versions. The time spent is divided into three criteria: *Value*, *Necessary waste*, and *Waste*.

- *Value:* Information that the plant need and that is created by the ME when they write or add the information to the PII is considered to be a task that provides value. It is information that does not exist before the ME adds it into the PII such as operation description, tools, and sequencing. Furthermore, the creation and release of the PII are considered to be of value to due it being the step that enables the plant to receive the valuable information.
- *Necessary waste:* A task that provides the necessary information to the plant but the ME does not create it by themselves is considered to be a necessary waste. Examples of this type of necessary waste are manually finding and transferring already existing information to the PII. This type of waste is not possible to remove directly but major improvement potential exists for the tasks.
- *Waste:* A task is considered to be waste if it does not contribute to valuable information for the plant. For example, system loading times and errors cause major waiting times.

In the following list, the preconditions for the observations are stated.

Preconditions for the observation of PII creation:

- All information had been released, no unnecessary waiting
- The ME had done pre-work, i.e. gathered and analyzed the necessary information and made decisions
- Teamcenter had low server stress (after a milestone and around 12'o clock)
- ME was highly focused on the creation process and had no distractions
- Does not include common restarts of the computer nor Teamcenter

4.3.1 Creation of PII: V0

The Value stream mapping, of the milestone V0, resulted in the following illustration:

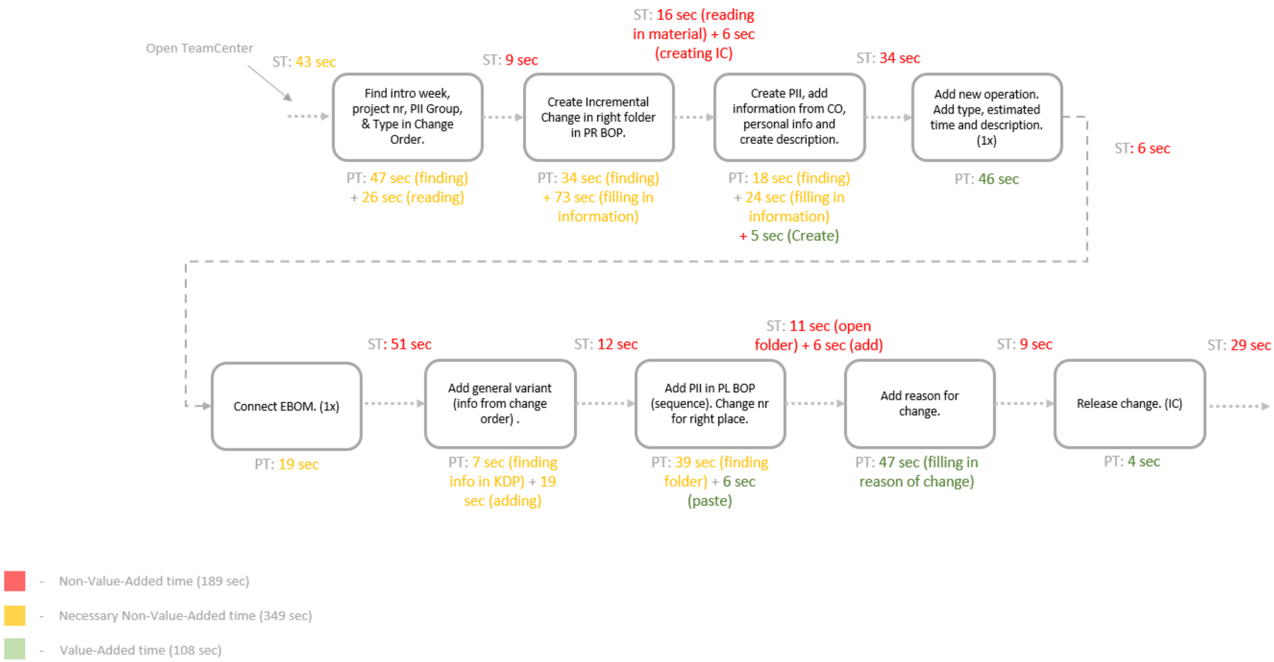

Figure 4.3: Value Stream mapping: V0

For better visualization, the raw data is presented in table form along with the total time spent in corresponding criteria.

Raw mean-time data is presented in the following table:

Table 4.3: Table of Value Stream mapping: V0

Process	Value	Necessary waste	Waste
Find intro week, project nr, PII Group & Type in Change Order	0	26 sec (reading) + 47 sec (finding) + 43 sec (open TeamCenter)	9 sec (software, loading time)
Create Incremental Change (IC) in the correct folder in PR BOP	0	34 sec (finding) + 73 sec (filling in information)	16 sec (reading in material) + 6 sec (creating IC)
Create PII, add information from CO, personal info, and create description	5 sec (create)	18 sec (finding) + 24 sec (filling in information)	34 sec (software, loading time)
Add new operation. Add type, estimated time, and description (1x)	46 sec (creating)	0	6 sec (software, loading time)
Connect EBOM (1x)	0	19 sec (connecting)	51 sec (software, loading time)
Add general variant (info from change order)		7 sec (finding info in KDP) + 19 sec (adding)	12 sec (software, loading time)
Add PII in PL BOP (sequence). Change nr for the right place	6 sec (paste)	39 sec (finding folder)	11 sec (open folder) + 6 sec (add)
Add reason for the change	47 sec (filling in reason of change)	0	9 sec (software, loading time)
Release change (IC)	4 sec	0	29 sec (software, loading time)
Total	108 sec	349 sec	189 sec

For better visualization, the raw data is presented in a pie chart. This shows the significant need for improvements in the current work process.

The total time of each criterion is presented below through a generated pie chart:

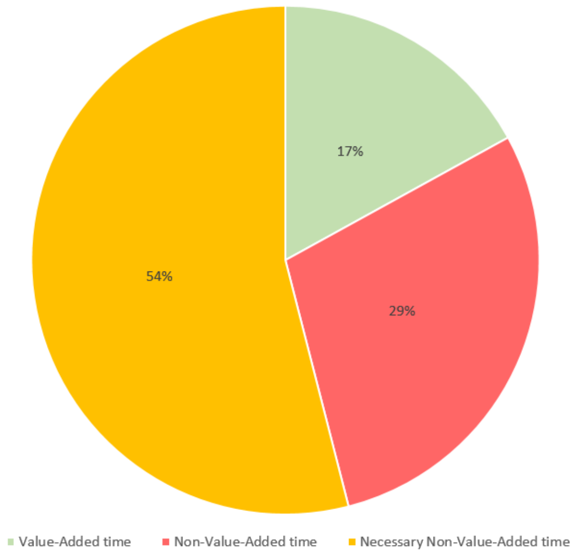

Figure 4.4: Total time spent ratio: V0

4.3.2 Creation of PII: V1

The Value stream mapping, of the milestone V1, resulted in the following illustration:

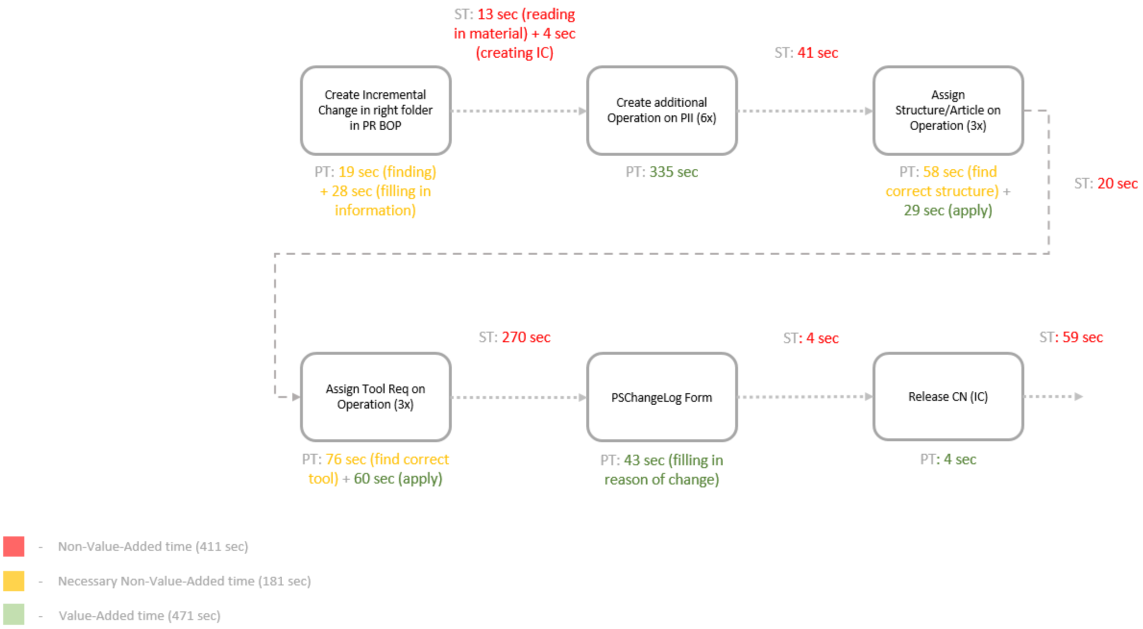

Figure 4.5: Value Stream mapping: V1

For better visualization, the raw data is presented in table form along with the total time spent in corresponding criteria.

Raw mean-time data is presented in the following table:

Table 4.4: Table of Value Stream mapping: V1

Process	Value	Necessary waste	Waste
Create Incremental Change (IC) in the right folder in PR BOP	0	19 sec (finding) + 28 sec (filling in information)	13 sec (reading in material) + 4 sec (creating IC)
Create additional Operation on PII (6x)	335 sec (creating)	0	41 sec (software, loading time)
Assign Structure on Operation (3x)	29 sec (apply)	58 sec (find correct structure)	20 sec (software, loading time)
Assign Tool Req on Operation (3x)	60 sec (apply)	76 sec (find correct tool)	270 sec (software, loading time)
PSChangeLog Form	43 sec (filling in reason of change)	0	4 sec (software, loading time)
Release CN (IC)	4 sec	0	59 sec (software, loading time)
Total	471 sec	181 sec	411 sec

For better visualization, the raw data is presented in a pie chart. This shows the significant need for improvements in the current work process.

The total time of each criterion is presented below through a generated pie chart:

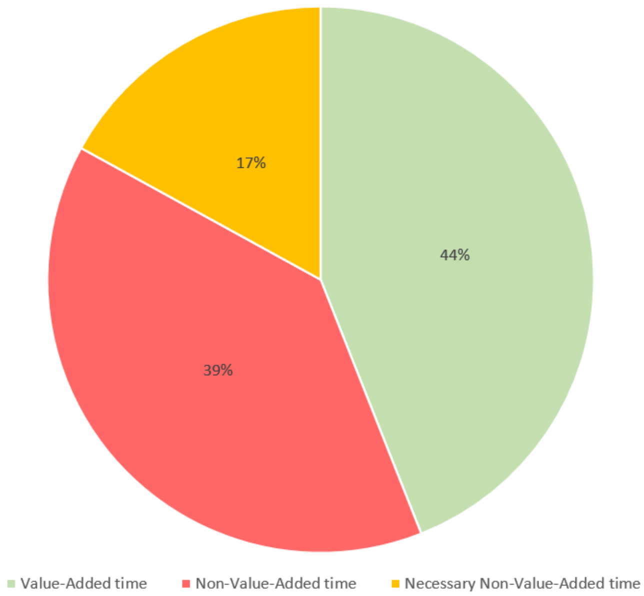

Figure 4.6: Total time spent: V1

4.4 Manufacturing department interviews

From the five semi-structured interviews with employees within the manufacturing department, five themes were identified as important for this thesis's purpose of finding where waste occurs. The five themes are further sub-categorized to enhance the reading of the results. Furthermore, some unstructured interviews with employees at the manufacturing department gave important information regarding some of the topics and will therefore be presented in this section as well. The identified themes were: Possible wasteful actions, highly time-consuming work, risks of low-quality work, consequences of system problems, and incorrect and missing information.

4.4.1 Possible wasteful actions

New demands, unsure of its necessity
Information on work height and work zone is a new demand that is added for each individual operation. The MEs' are unsure of how much value it creates for the factory, especially due to the height being a recommendation because all factories can not accommodate all heights, and explained that it has increased the administration workload. One ME was especially concerned with the issue of creating the

information for each and every operation when for example the pre-station only has one set height. Another ME thought it was illogical to add more administration workload when the system already works poorly.

Double-check completed work
Two of the MEs' described when they have released the PII, they can not proceed with the belief that everything is completed. Instead, they need to double-check their work by searching for the PII in WEB search to ensure that the changes were applied. In some cases, information could be missing or the revision can not be found, even though it looked complete in TeamCenter. Furthermore, it takes 30 min until the changes are visible in WebSearch and the ME can control the updated PII. However, one of the ME explained that they had gotten directives that if the information is correct in TeamCenter, then they do not have to double check it in WEB search.

Uncertainty of how the system with IC works
Lastly, some MEs' believe that they need to create an IC to be able to send the PII for time setting. However, the Time specialist explained that it is done in vain, the ME can send the PII on time setting without creating an IC, thus removing the several extra steps, for example, adding a reason for the change and releasing the IC. Relating to the time setting, if the intro week for PII changes, the ME can end up sending the PII for time setting once again, resulting in double work for both the ME and the Time specialist. The Time specialist mentioned that it in some cases has resulted in the program adding both separate time settings together, thus causing invalid time settings if it is not caught in time.

4.4.2 Highly time-consuming work

Operation pictures
The picture creation was brought up as highly time-consuming and several of the MEs' questioned whether the pictures are used downstream in production. It was described that each operation should be represented with one picture and two MEs' estimated that the picture creation for one PII takes roughly 20-30min. However, the time specialist explained that pictures are one of the most important pieces of information they use when calculating and determining the operation times. Another time-consuming issue with the pictures is the demand for writing the intro week on the pictures. One ME describe that when projects were postponed, each picture had to be updated with the new week. The ME described it to be unnecessary without adding any value for anyone. However, new directives were given to ease the workload by removing the demand.

Updating the structure in the PII regardless of the type change
When R&D updates or removes a structure, the ME needs to put administration work time into updating the PII, sometimes it can even occur dozen times between milestones. One said that the time was mainly put into updating operations and pic-

tures but another ME explained it to be a very unnecessary step for them. For their area, the software is often the reason for the updated structure and thus operations and pictures do not need to be updated. However, the ME still needs to update the structure due to a new structure number in some cases. If a structure is removed, it is automatically removed from the PII. However, the ME must update the PII by creating an IC and a reason for change even in the scenario when only one of several hardware identical products is removed and the operation method remains the same.

Slow, inefficient and varying quality of the tooling field
The tooling field was brought up as time-consuming by two of the MEs'. One explained that the tooling number often changes and that it would be good with a similar solution to EBOM structures so that it automatically updates. The other explained that the tooling field itself is very time-consuming to fill in, the drawing number can take about 10-15min to fill in due to loading times. Furthermore, sometimes the added drawing number does not appear in the PII after it has been added, forcing the ME to double-check their work by creating a PDF.

Possible inefficient way of writing each operation step
Some PIIs' have a large number of operation steps and all the MEs' explained that the creation of the operation steps in V1 is one of the activities that take a long time. One ME thought that it may exist a more modern and faster way of presenting the steps instead of written text, for example, a video.

Creation of one new IC for each PII that needs to be updated
Other areas which were explained to be time-consuming were the demand for creating one new Incremental Change (IC) for every PII. There is a possibility for creating one IC on a bundle of PIIs'. However, there is a complication when an adjustment has to be done on a PII within the bundle. For example, if the intro-week changes for one PII in the bundle, the changes will be applied to the whole bundle. Furthermore, the initial creation of the PII was as well explained to be time-consuming, with one new IC needing to be created for each new PII.

4.4.3 Risks of low-quality work

Several topics were identified as risk areas for producing low-quality work, mainly concentration, documentation, and actions that are not standardized among MEs'.

Concentration
As for concentration, when the MEs' have added some information to the PII the system will be loading for several minutes depending on the load of the system and which type of information was added. During this time, it was mentioned that it is easy to become distracted. For example, opening emails, starting a conversation, or taking a coffee. One ME explained that if they would not multitask during the loading times, for example, by performing other administration work, they would not be able to perform their work on time. Several of the MEs' mentioned that they

often can get help from each other when facing issues with TeamCenter, and even if it was mainly described as positive, they acknowledge the risk of forgetting what they were working on before they were asked to help. Lastly, two MEs' especially described the scenario of working administratively for the last 30min of the day and occasionally receiving an error that forces them to restart the computer or often facing slow systems which hinder them from completing their work. This forces the ME to remember what steps were not completed until the next workday, facing risks of needing to reschedule their work or forgetting to add the information if other more urgent tasks occur.

Risks of missing information in the documentation
Some parts of the information from R&D are automatically included in the PII, for example when a screw is included, the CC-classification and torque values automatically occur. However, one ME explained that information regarding ESD is retained from R&D during the P-FMEA work and thus is not automatically included when a structure is consumed in the PII. Furthermore, the information from the P-FMEA is not automatically connected to the PII but needs to be added manually by the ME thus for some information the ME needs to add the same information twice, one time in the P-FMEA and one time in the PII. Moreover, it puts higher pressure on a good hand-over when MEs' are changing positions, if the ME has had discussions with R&D about ESD markings and has not yet documented it, the new ME need to be informed about the subject.

Low standardization regarding cross-functional meetings and keeping track of changes
Lastly, all of the MEs' described that they had quite good and frequent communication with R&D, however, it very much depends on the ME on how often they communicate and it was not presented as a standardized way of working connected to the cross-functional meetings and communications. Furthermore, due to the MEs' not updating the PII directly when information changes, the ME needs to remember and document what should be changed later in the PII when they are more certain that the information will not change. It is up to the individual how to document the information, PowerPoint, Excel sheets, and notebooks were some examples of tools they use.

4.4.4 Consequences of system problems

During all of the interviews with employees at the manufacturing department, several issues with the software were brought up as a large reason for the high amount of administrative time being spent on PII creation. However, the focus point of the software is not the errors and issues but rather the consequences.

"Quick" fixes that do not solve the underlying problems
Restarts of the software and computers were a reoccurring theme in the interviews, and three types of scenarios were described. During their workday, to avoid the pro-

gram from crashing they have to close the software for breaks and lunches. Therefore, they have to choose between completing the work before each break or closing the program when something is unfinished and thus risk forgetting what they left unfinished. Accountability checks are used by the ME to check if some updates have been made on for example structures, however, every other week it stops working, and to solve the issue the ME has to restart their computer. The loading time for the system is often long, especially mentioned were the shifting from one PII to another. One of the MEs' explained that restarting the software is used as a solution to make the software work a bit faster, however, they have heard rumors say that it may slow down the system.

Errors and bugs are other themes that were reoccurring. The error messages were described as written in computer codes and impossible to understand, often leaving the ME confused about the issue and not being able to solve it. The three solutions that were described by the MEs' were to either wait until the next day, call IT, or swap between the workbenches in the software.

Two of the errors that ME frequently stumble upon but are unable to solve by themselves are "Locked out of session" and "Double session". To solve the error, they either call IT and hopefully, they are able to continue their work within some hours depending on IT's response time. However, it was mentioned that they should not contact IT with some types of errors if it is not crucial and instead wait until the system restarts which occurs during the night. Thus, they have to wait until the next day to continue their work. According to one of the MEs', these types of errors occur more frequently during their peak time of administrative work, which often is before a milestone.

Another issue described was the bugs, where some parts of the PII mysteriously stop working. For these cases, waiting until the next day was also mentioned as one of the solutions. Another solution that the ME use is to swap between the workbenches, shifting from the new recommended workbench to the old workbench. For most of the interviewed MEs', the recommended workbench seemed to work poorly, possibly having several bugs, causing issues to fill in some types of information.

Plan administrative work due to overburdened PLM system

Overburdening of the system at specific times was mentioned several times during the interviews. Before milestones and the afternoons were described to be the times when the system works the worst, resulting in a high increase in the loading times for all parts of the PII creation. Adding structure was pointed out as a specially slow task when the system is overburdened and when many employees add structure at the same time. The overburdening causes MEs' to plan their administrative work, for example by arriving at work at 6'o clock when they have many PIIs' to work with.

4.4.5 Incorrect and missing information

Delays due to late information

For the ME to be able to perform their work, they need the model to develop and verify the assembly. Without the model, there is no basis for simulations. Some possible reasons why the model can be missing were mentioned. R&D may have missed releasing the structure, they may be delayed or the part is developed by a supplier. When the supplier develops the part, it may take a longer time before R&D are able to include the model in the software. Besides not being able to verify the assembly, the late information causes issues in the Mechanical integration meetings. Not knowing how the part will fit together with surrounding parts can cause late redesigns.

Missing information in the CO

Other types of data that may be missing or incorrect is any type of information that the CO holds, such as the number of screws. Consequences of missing and incorrect information can be inaccurate equipment, wrong line balancing, or purchasing the incorrect amount of parts. The MEs' explained that they mainly have dialogues with the R&D when information is missing and it was described as mainly good communication between them. It was also mentioned that they can write a Vira, i.e., sending R&D a notice of for example that some information is missing. However, some experience is that it takes a lot more administrative time to write the Vira than to contact the responsible employee at R&D and ask for the information, especially because they need to contact the R&D employee before they send the Vira anyways.

Screw specifications which are provided by R&D are a type of information that needs to be double-checked by the ME if it is included. When a screw is added to the PII, information such as torque, is automatically added to the PII. However, in some cases, the information could be missing. One scenario which had occurred was that R&D had forgotten to include the torque form.

Another issue related to when the R&D updates or creates the CO is that the structure is not visible for the ME until 24h later. For example, if the ME notices that the R&D has missed adding a structure and contacts them to solve it, they have to wait until the next day to continue their work on adding that structure to the PII.

4.5 Plant department interviews

The interviews of the employees within the Plant department are divided into two groups due to them working at different stages of car development. Plant Launch is involved in the early phases and Plant technicians are involved in the later stages and mainly when the car is being manufactured. Because of their involvement at different stages, they have different tasks, demands, and views on the PIIs'.

4.5.1 Plant Launch

Plant Launch employees are involved in the car projects from the early phases, giving input and recommendations. When the car project is more mature, around the VP phase, they hand over the work to the employees at the factory. Three themes were identified in the interviews: Valuable information in the PII, Lack of or slow information, and consequences of software issues.

4.5.1.1 Valuable information in the PII

For Plant Launch, the most important information is the EBOM, structure, operation pictures, and description of the operations. Especially mentioned was the importance of the operation pictures, which the employees check even before they read the operation description because it provides an overall understanding. Furthermore, the necessary information for phase V1 was described to be the structure, EBOM, and an initial thought of how the assembly should be done. However, they clarified that it would be good if the EBOM existed in V0, which it should be according to the PII regulations, but it rarely does and sometimes there is not even a created PII in V0.

The information from the P-FMEA was described to be time-consuming to find and it was even mentioned that not everyone has the access to enter the program where the information exists. The employees wish that the P-FMEA were integrated or connected with the PII to ease their workload of unnecessary searching.

4.5.1.2 Lack of or slow information

The interviewees mentioned that updates of the PII can be very slow, which they described as being mainly because the ME does not always receive the information from the R&D department that a change has been made. Therefore, they sometimes check for updated information in KDP, which is the place where R&D applies their changes. The interviewees wish that the information would reach them directly instead of it being slowly updated or even lost. Furthermore, they would like the PII to be updated as soon as possible after the CO has been released, though they understand that it is not possible between the V0-V2 phase due to the high amount and fast changes. For example, it is important that the information about the structure is up to date, otherwise, they risk ordering the wrong part or the wrong amount.

It was further described that updates of the PII owner are especially slow. They often need to contact the PII owner and when the information has not been updated they need to search for the responsible ME which is highly time-consuming for them. However, one possible explanation that was mentioned is that some ME have had to temporally take over extra PIIs' when a coworker has quit.

4.5.1.3 Consequences of software issues

A huge part of the problems that the Plant Launch experience is the issues with the information transferring between TeamCenter Classic and TeamCenter WebSearch. The ME writes the information in TeamCenter Classic but the employees at Plant Launch reads the information in TeamCenter WebSearch. About 80% of the time, the information in the PII has not been correctly transferred between the programs which is an automatic process. The solution today is to call the ME which then emails the necessary information. The interviewees said that the MEs' has to put a lot of effort and time to solve the information issues even though they have correctly entered the information in Teamcenter Classic.

4.5.2 Plant technicians

Plant technicians mainly work with the PIIs' when the factory begins to manufacture the car. Few employees work with the PIIs' in the early V0-V2 stages while most work with completed or updated PIIs' when the production has started. The technicians receive updated or new PII information and help the production to balance it and inform about the changes. The PII information is manually transferred by the technicians into the factory's own system, SBS toolbox. Four different themes were identified in the interviews: Valuable information in the PII, information used at different times and by different employees, information-related issues, and software issues.

4.5.2.1 Valuable information in the PII

Similar like the Plant Launch described, the operation pictures and structure are some of the most important information the Plant uses. The pictures were described as especially important for complicated assemblies, e.g., "assemble X in the line of the car roof" is made clear with a picture showing what part of the car it refers to. However, the operations in the PIIs' sometimes get divided into several stations. Thus, the pictures show both the operation performed at the station and those performed at other stations, forcing the Plant to create new pictures.

The newly added information about work height and work zones was described to be a good addition which will help them to balance the lines more efficiently. Furthermore, due to the operations in the PIIs' can be placed at different stations, it was mentioned that the information should be written at the operations, which it is today.

4.5.2.2 Information used at different times and by different employees

The information in the PIIs' is used by different employees and at different times. The structure is used to know when an article is added or removed from a station, the technicians use the information but not every day. The operators use both the operation pictures and descriptions but not on a daily basis. The sequencing of the PII is used mainly at the beginning of the cars' life cycle at the factory when they are planning the manufacturing, but due to optimization, they can change the sequencing.

4.5.2.3 Information-related issues

Every change on the PII prompts a message to the Plant, which they manually need to oversee and if needed, transfer the information to their system. Due to the PIIs' being generic, i.e., the same for all the factories, the employees need to manually check the PIIs' for whether or not the change affects them. Sometimes, the MEs' make big cleaning work on their PIIs', i.e., make a lot of smaller changes and often during the end of the week. It creates stress for the employees at the Plant, who rapidly need to look for any urgent or important changes that may affect them soon. Furthermore, sometimes only the issuer of the PII changes, it is important for them to know who is the responsible ME but they explained that it takes a lot of administrative time to only add the new name.

Sometimes there is a lack of information in the PIIs'. It occurs that the operations are set to 0 Time Measurement Unit (TMU), which causes issues because it is one of the parameters for deciding how many operators are needed and thus wrongly assumes the car to be cheaper to produce. Reason for change was also pinpointed to be a lack of information issue. It occurs that several changes on a PII are described with only one change. *"The reason for the change was described to be that a picture was updated, but the real reason was that an operation had been removed which was not mentioned".*

The numbering system of the operations makes it difficult for the employees to detect when and which operation has been deleted. For example, when operation nr 20 is deleted, the previous operation nr 30 becomes the new nr 20. Furthermore, due to the sequencing can change from the one that ME described, it can be difficult for the employees to find which PII needs to be performed before another. The interviewees suggested that it could be a good idea to add which PII needs to be completed before their PII.

When issues occur, it can take a long time to get it fixed. The employees contact the responsible ME but they often want them to send a Vira, and sometimes it is confusing about who should take the responsibility to fix it, it can be either the global or local engineer. However, they do often have good communication with the MEs'. For example, when the ME is new in the position and the drawing numbers are missing, they try to collaborate to find the correct information. It was further described that they would like to increase the understanding between the ME and the plant.

4.5.2.4 Software issues

Moreover, the issue with information transferring between TeamCenter WebSearch and TeamCenter Classic was also described by the Plant. They recently discovered that lots of information were missing in the PII when they looked in TeamCenter

WebSearch and contacted the ME. However, when the ME checked in TeamCenter Classic, they saw all the information that the Plant could not see.

4.6 R&D department interview

From the interview with the employee at the R&D department, two themes were identified: Lack of information and long lead times and cross-functional understanding.

4.6.1 Lack of information and long lead times

The interviewee described that communication with the ME is important and even essential. The Change Order which is sent to the ME when a product is updated does not include information about the reason for the change. Furthermore, in the case when a supplier designs the part, it takes a rather long time until the part is added to the EBOM due to several approval steps. Therefore, the ME must trust that the communication with R&D provides the needed information, such as the newest updates and changes.

Sometimes when R&D uses suppliers to develop a design, there is a need to gather necessary demands and information before the actual time plan. This is due to longer lead times when using a supplier and thus they could freeze the design beforehand of the overall plan. Even though they freeze the design, they continue to listen to demands which sometimes causes late changes. Furthermore, it was mentioned that they may miss moving activities connecting to the milestone where the design should be frozen.

4.6.2 Cross-functional understanding

Regarding the overall understanding between the different departments, the interviewee mainly described it to be quite good. They have a good-working collaboration where they try to understand each other's viewpoints and receive early input. The interviewee described that they rarely have collaborations with for example tooling or the plant, it is mainly the ME that acts as a middleman between the departments, providing and collecting information both up- and downstream. Furthermore, the interviewee would like an increased cross-functional understanding because some areas could potentially work better.

One case is adding some particular attributes, such as ESD and scanning. There can be a lack of understanding from the R&D on how the attributes affect the ME and what type of work and cost it entails for the ME to develop the instructions. *"We would like to protect our product and thus checks the box for ESD, however, when the ME questions if it is needed, they may find out that it was not a must"*.

When there is a dispute between the departments, which seldom occurs, it is often because they do not understand each other's viewpoints and especially when it involves costs. Furthermore, the interviewee was not accustomed to the Vira system, with the only exception of remembering being added as a CC (Carbon Copy) once in a while.

4.7 IT department interview

From unstructured interviews with employees at the IT department, some further understanding regarding the current state and future of the software has been developed.

There is already an understanding that the speed of the software has been decreasing since its implement ion, there is no definitive answer to why but some possible hypotheses were the switch to cloud-based servers and the large amount of created ICs. Even though they conducted tests before transferring to cloud-based servers and found it to not decrease the speed in a significant way, it was described to be a possible reason for the decreased speed. Furthermore, the IC system was described to have both positive and negative traits but with the large amounts of ICs, it is probable that it causes system slowdown due to the huge amount of data that must be read to open files.

Regarding the IC system, it was mentioned that the PLM provider no longer updates the system and has moved towards other types of revision systems. There are already plans for updating and improving the PLM system and thus the IT department is gathering input on which functionalities are needed. Throughout the Teamcenter Classic, lots of effort and resources have been put into solving issues. For example, when several changes are connected to one IC, the IT department may need to assist the ME with help to separate them, which was mentioned to not always be possible, and thus in some cases the ME must create brand new PIIs'.

4.8 Work method validation

The work method used to analyze the ME process of creating PIIs' was tested on a similar process to ensure the validity of the method. The work method was applied to the Time specialist work within the exact PLM System. The Time specialist's task is to accurately set times for the different operations within the PIIs', using a SAM DATA CARD.

4.8.1 Value Stream Mapping: Time specialist

The Value stream mapping, of the Time specialist, resulted in the following illustration:

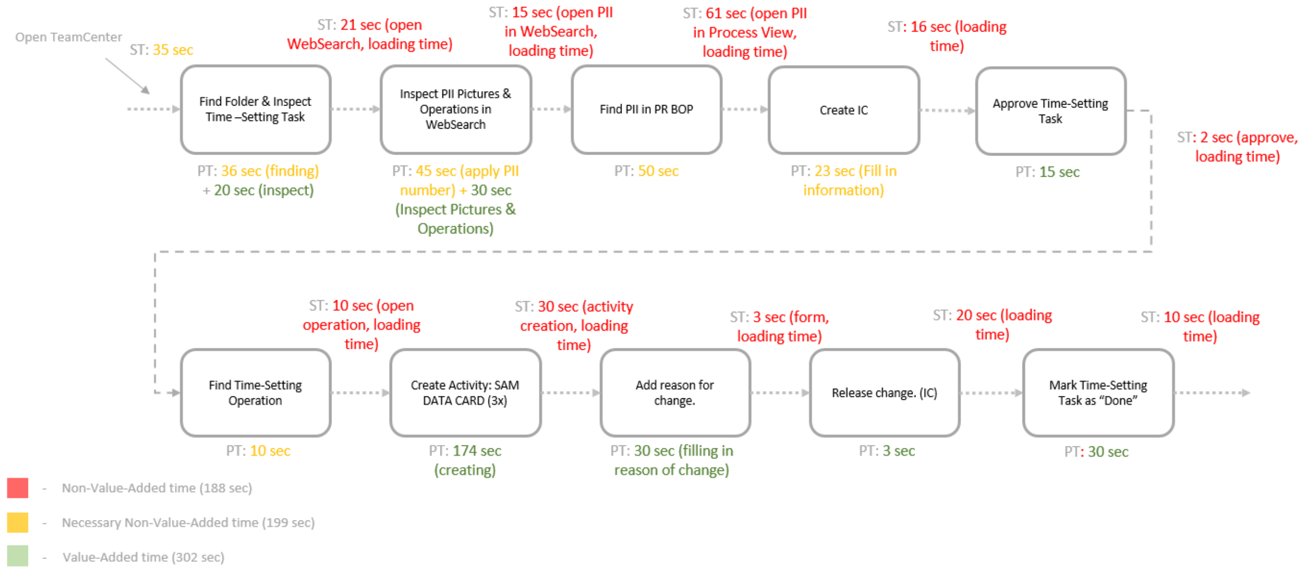

Figure 4.7: Value Stream mapping: Time specialist

For better visualization, the raw data is presented in table form along with the total time spent in corresponding criteria.

Raw time data is presented in the following table:

Table 4.5: Table of Value Stream mapping: Time specialist

Process	**Value**	**Necessary waste**	**Waste**
Find Folder & Inspect Time-Setting Task	20 sec (inspect)	36 sec (finding) + 35 sec (open TeamCenter)	21 sec (open WebSearch, loading time)
Inspect PII Pictures & Operations in WebSearch	30 sec (Inspect Pictures & Operations)	45 sec (apply PII number)	15 sec (open PII in WebSearch, loading time)
Find PII in PR BOP	0	50 sec	61 sec (open PII in Process View, loading time)
Create IC	0	23 sec (Fill in information)	16 sec (software, loading time)
Approve Time-Setting Task	15 sec	0	2 sec (approve, loading time)
Find Time-Setting Operation	0	10 sec	10 sec (open operation, loading time)
Create Activity: SAM DATA CARD (3x)	174 (creating)	0	30 sec (activity creation, loading time)
Add reason for change	30 sec (filling in reason of change)	0	3 sec (form, loading time)
Release change. (IC)	3 sec	0	20 sec (loading time)
Mark Time-Setting Task as "Done"	30 sec	0	10 sec (loading time)
Total	302 sec	199 sec	188 sec

For better visualization, the raw data is presented in a pie chart. This shows the significant need for improvements in the current work process.

The total time of each criterion is presented below through a generated pie chart:

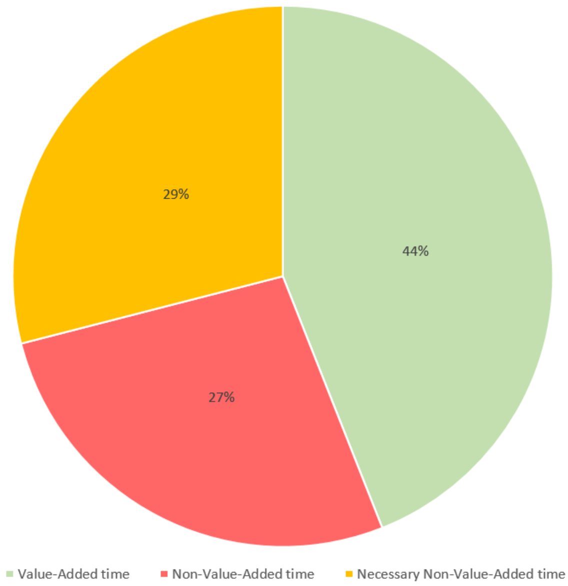

Figure 4.8: Total time spent: Time specialist

4.9 Workshop

The workshop comprises three distinct cases, each addressing specific problem areas identified during the interviews. These problem areas arose from conflicting perspectives among one or more departments, thus confirming their significance. The cases are thoroughly described, and their outcomes are presented in the subsequent subsections.

4.9.1 Case 1: New requirement to add recommended height and work zone

The PIIs' have recently received a new requirement to display the working height and the work zone of operations. This should make it easier to balance and increase the ergonomic situation of the production lines when similar working heights and working zone operations can be held together.

The production technicians think this is a great addition and will make their job easier, while MEs' think that this is an extra tedious step that takes time in an already overwhelmed and suffering PLM system. The height and work zone needs to be applied in every operation whenever the height changes or not to the next operation. Currently, the work- height, and zone are written on the operation level and on every operation within the PII.

Case Question: How can the current way of working be improved so that it benefits all parties involved?

The Case resulted in the following outcome:

- The information is valuable for production and should stay.
- The information could, in theory, be auto-generated from the visual model (EBOM) and be applied automatically to the PII. The visual model shows in what zone and at what height the assembly process takes place. This should be further investigated and be given as input to the developers of the next PLM system.
- Clear and direct instructions need to be implemented that will standardize the way the information will be applied. Today there are various ways MEs' apply this information.
- The information should be available to be applied at a PII level. Eliminating the task to apply the same work height and zone at every operation (if that is constant throughout the PII).

4.9.2 Case 2: The current way of creating process pictures is inefficient and takes a long time for MEs' to perform

The current way of creating process pictures takes a large amount of time and is of varying quality, depending on the ME creating them. The pictures are valuable for both Time specialists, in terms of understanding distances and assembly processes, as well as production technicians, showing operators how to assemble the products and production balancing.

The current process of creating pictures is inspecting the virtual model (EBOM model), taking screenshots of the areas of interest as well as an overview picture, importing into Microsoft PowerPoint, attaching operation balloons, saving PowerPoint slides as PDF, and then uploading the PowerPoint and PDF files on the corresponding PII.

Case Question: How can the creation of pictures be more efficient and quality-assured to visualize operations?

The Case resulted in the following outcome:

- The pictures could, in theory, be partly auto-generated by implementing a fully integrated PLM system. Removing the need for 3rd-party software. This should be further investigated and given as input to the developers of the next PLM system.
- The way of creating pictures needs to be further standardized, to reach a company-wide quality standard. This can be done by creating tutorials on how the pictures should be displayed. This material can then be a part of the future onboarding process for MEs'.

- Further analysis of the information depicted in the pictures is necessary in order to effectively map the requirements of the end-customers.

4.9.3 Case 3: The understanding of how deliveries affect the work of other departments

There are currently areas where communication and understanding between different departments are lacking. Specifically, when R&D delays the release of certain information, it can cause challenges for the MEs' in completing their work on time. As a result, R&D may face difficulties in recognizing the needs of their end-customer, which in this case is the ME department.

Additionally, there is a lack of understanding regarding how the PIIs' respond to changes and how the PII information is transformed within SBS Toolbox. These changes can have a significant impact on the work of production technicians, without the MEs' being fully aware of it. Consequently, the ME department may face challenges in effectively communicating these changes to the production technicians in certain situations due to a lack of knowledge and understanding.

Case Question: How can we enhance the comprehension of how various actions impact different departments?

The Case resulted in the following outcome:

- There is a necessity to develop informative materials that promote better understanding of needs between departments. These materials should be integrated into the onboarding processes of respective departments and closely monitored for effectiveness. Additionally, the company should prioritize enhancing the competence of mentorship programs and expanding its reach by including mentors from both upstream and downstream departments. By doing so, valuable knowledge and insights can be shared, fostering stronger collaboration and alignment throughout the organization.
- In order to foster a stronger sense of community and unity among the departments, it is beneficial to organize more cross-functional meetings. These meetings can serve as platforms to showcase the utilization of information across various departments and demonstrate how collaborative work can be enhanced. By highlighting the interconnectedness of tasks and the shared goals, these meetings promote better understanding, and cooperation, and encourage increased collaboration among the teams.
- Enhancing the integration between TeamCenter and SBS Toolbox is crucial to enhance the reliability and efficiency of the information flow. A top priority is to explore options for eliminating the dual environment of PLM systems, thereby eliminating the need for converting information from one system to another. This approach aims to streamline the process and minimize potential errors or discrepancies caused by information transfer between systems.

5
Discussion

This section begins with a summary of the identified inefficiencies followed by a discussion of the results connected to the two research questions. Thereafter, a discussion regarding the methodology and the implications of our findings are presented.

5.1 Summary of findings

The current work process undoubtedly includes wasteful actions that require immediate attention. This section will identify waste associated with each data collection method from a lean administration perspective.

5.1.1 Value Stream Mapping

The VSM analysis revealed significant inefficiencies in the current work process of creating and adjusting PIIs'. The subsequent section highlights the key areas of waste identified in relation to lean administration.

Searching for information & data

- Significant time is being devoted to searching for and transferring existing information from third-party sources. This duplication of effort not only exists but also poses a great quality risk during the data transfer process.

Badly integrated system

- The PLM system lacks the display of, or only views coded, error messages, posing challenges for MEs' in effectively identifying and resolving issues within the PLM system.
- The PLM system occasionally crashes without any apparent issues, requiring a restart to restore functionality.
- The current PLM system employs Incremental Change (IC) as its revision control mechanism. While IC is effective for smaller-scale applications, its extensive usage within the system leads to performance slowdowns.
- The PLM system occasionally encounters connectivity issues with dependent systems, making it impossible to execute work tasks such as applying "Tool requirements".

Waiting times

- The PLM system suffers from extensive loading times. This cause the MEs' to feel demotivated and irritated.

Incorrect processes

- Some processes risk not fulfilling end-customers demands, e.g. quality- or system error problems. Standardization and automation are needed to remove this risk.

5.1.2 Interviews

The interviews revealed significant inefficiencies in the current work process. The subsequent section highlights the key areas of waste identified in relation to lean administration.

Waiting times

- The PLM system causes major waiting times in the form of errors, restarts, slow synchronizations between systems, and loading times.
- Waiting for information from the R&D department can cause severe waiting times.

Incorrect processes

- Unnecessary creation of IC for time setting takes time and does not have any effect. They may also send a PII for time setting twice due to the IC system, causing double work for both parties.
- The varying quality of process pictures does occasionally not fulfill the customers' demands, causing either ME or Plant to redo work.

Overproduction

- Manually write height and zone on all operations which in some particular cases are not used.
- Always updating the PII due to changes in structure can cause unnecessary extra work depending on the type of change.
- Due to R&D's lack of some understanding of how their information affects the MEs', the ME may perform extra work due to higher demands than necessary.

Badly integrated systems

- There are several areas where information is manually transferred from one system to another, creating opportunities for quality issues. For example, adding CO and PFMEA information manually in the PIIs'.

Producing faulty services

- Due to system issues with synchronization, the ME may produce a PII which do not fulfill the need of the Plant, causing re-work for the ME.
- Due to low standardization regarding keeping track of changes that are not changed immediately, there is a potential risk of forgetting to add the information.

5.1.3 Workshop

The workshop revealed significant inefficiencies in the current work process of many departments. The subsequent section highlights the key areas of waste identified in relation to lean administration.

Badly integrated system

- Some information should be able to be applied on the PII level instead of the operation level. This will greatly reduce the time spent on applying information that doesn't necessarily change on every operation within a PII.
- The IT Department should investigate integrating SBS Toolbox and TeamCenter alt. Fuse TeamCenter and SBS Toolbox into one PLM system. This would eliminate the confusion about what information gets transferred automatically and the systems sync issues.
- The IT department should investigate the option to auto-generate height and work zone from visual models (EBOM) and integration of process picture making removing the need of 3rd party software and tedious re-uploads.

Producing faulty services

- MEs' currently do not have a standardized way of creating process pictures, resulting in varying quality. The time spent on creating bad pictures is therefore waste.
- MEs' lack a standardized method for determining work height and work zone, leading to occasional wasted time spent on applying incorrect information. This time waste needs to be addressed.

Underutilized creativity

- Currently, the different departments have complications to understand each other. Clear and informative material should be developed to increase understanding in order to remove misconceptions and delay in delivery. To increase collaboration, utilize creativity, and a sense of community more cross-functional meetings should be held.

5.2 Answer for RQ1

RQ1: What inefficiencies can be identified & where in the administration of Process & Inspection Instructions

Various inefficiencies with different severity have been found throughout the whole administration process of creating PIIs'. Furthermore, information from interviews also highlights inefficiencies that occur both before and after the main activity of creating the PII, causing further inefficient work for the ME.

As can be seen from the results of the VSM, the V0 phase has a higher percentage of necessary non-value-added work than V1. The V0 phase is mentioned to be the easier phase, likely due to the activities of transferring existent information. In the V1 phase, the ME performs more value-added work by creating elaborated descriptions of the operations and adding tools. However, information from R&D that does not change the information that the ME creates must also be added to the PII in the current state. These types of changes may occur in all phases and do not include any value-added work performed by the ME except the task of adding a reason for change.

One of the commonly mentioned inefficiencies, which also could be seen in the VSM, is the system waiting times. The inefficiency occurs throughout the whole process of creating the PII, every time information is added or a click to open a drop-down list is made, the system loads for a long period of time. Depending on the time of the day, the stress of the server and how long the program has been running, the issues are more or less severe. Due to the loading times, the ME may lose concentration and either take breaks or start with other tasks, potentially creating further issues with more waiting times and forgetting to add the rest of the information.

Manually transferring information from one place to another could be seen in the VSM and described by the interviewees. The ME transfers information from e.g. the CO and P-FMEA, and the Plant transfer information from the PII to their system. Creating information and then manually transferring it is not only an unnecessary and time-consuming task, but it also increases the risk of introducing incorrect information. As Doyle (1985) describes, misreading and entering wrong characters are errors that may occur when entering information and the most effective way to eliminate the errors is to avoid human handling.

It was found that incorrect information is not only at risk of being created in the PII creation process but it is also introduced when the information enters the process and when the PII exits. The MEs' experience that the CO both can have incorrect and missing information. Causing the employee to take time to present the issue to R&D and then wait for the system to become updated with the new information. The synchronization was mentioned to work poorly, creating double work for the ME to not only add the information in one system but also send it by mail. This phenomenon was mentioned by three individual employees, however, the vastness and frequency of the issue were not studied in this thesis.

Another type of inefficiency is the misunderstanding between the departments. Due to insufficient communication and knowledge sharing, the departments do not understand how their information affects others. The lack of understanding may cause a lower work ethic, lower-quality products, and frustration (Zandin 2001). For example, the MEs' are unsure if the pictures of the operation are used and thus they may perform less on the task due to not knowing if anyone uses the information which takes a long time for them to create.

It can also be discussed how efficient the processes for creating operation pictures and descriptions are. The creation of pictures contains cutting and pasting from one system to another, creating 2D pictures from 3D models. Assemblies must be described in highly detailed step-by-step instructions, with some complex PIIs' having two-digit operation steps. The employees at the Plant department and the Time specialist have all said that the information is utterly important to them, but it may exist more time-efficient ways of presenting the information.

5.3 Answer for RQ2

RQ2: How can the administration of Process & Inspection Instructions be improved to address existing inefficiencies?

Given the diverse range of issues identified across different parts of the workflow, it is not feasible to implement a single solution to address all these problems. Taking this into consideration, in order to tackle the inefficiencies effectively, it is advisable to concentrate on a select few existing waste categories per improvements suggestion. By doing so, we can maximize the impact on the work process and achieve substantial improvements.

With the discussion from Section 5.2 and the findings of the workshop, four key suggestions for improvement have been identified. The subsequent section provides a concise discussion of these areas and highlights the potential outcomes that could be achieved through their implementation. Furthermore, the areas have been prioritized based on the urgency of implementation, taking into account the extent to which they can address existing inefficiencies in relation to the effort required for implementation.

Improve the PLM system:
Improving the PLM System can address various existing issues, but it requires significant time and resources. A comprehensive overhaul of the system is imperative to address the multitude of bugs and errors. Additionally, measures should be taken to enhance the system's performance, eliminate inefficient steps identified in the VSM, and increase the automation of information. This can be achieved through improved synchronization between systems or by exploring the possibility of integrating all dis-

parate systems (SBS ToolBox, WebSearch, and TeamCenter) into a unified platform. By implementing these improvements, the organization can streamline its processes, reduce errors, and boost overall efficiency.

The suggestion is given a "high" priority due to the current PLM system's negative impact on Volvo Cars' organizational agility and financial performance. This includes extended product development lead times, reduced ability to promptly address late design changes, and MEs' extensive idle time when working with the system.

Key affected waste areas: *Searching for information & data*, *Badly integrated system*, *Waiting times*, *Incorrect processes* and *Overproduction.*

Increase Community among Departments:
Cultivate a strong sense of community across departments, promoting the exchange of valuable knowledge and insights, thereby fostering enhanced collaboration and alignment within the organization. This could be achieved through the promotion of cross-functional meetings, which serve to boost collaboration and harness collective creativity. Additionally, establishing mentoring programs across departments to instill a sense of ownership and significance in delivering high-quality products, ensuring that each department is actively engaged and invested in seeing their contributions utilized to achieve superior outcomes. Increasing the sense of community can also help eliminate misunderstandings and proactively address problems, instead of using a reactive problem-solving approach.

The suggestion is assigned a "Medium" priority since it is not an urgent requirement, as the departments already collaborate to some extent.

Key affected waste areas: *Underutilized creativity*, and *Incorrect processes.*

Standardization of Work Processes:
A crucial initiative to minimize re-work and confusion of work execution is the implementation of standardized work processes. According to Zandin (2001), this could be done by assembling a team of experts, in the corresponding process, to create direct and efficient instructions. This material should be learned and followed by every corresponding department, to ensure consistent application of information across the company. The result of this leads the company to a company-wide quality standard and the ability to further develop the work processes in a unison manner.

The suggestion is given a "High" priority, as it will reduce time spent on non-value-adding tasks, boost the work morale of personnel, implement a company-wide quality standard, and foster unity among work ethics.

Key affected waste areas: *Producing faulty services*, and *Incorrect processes.*

Improved On-boarding & Development of Introduction material:
To address the existing confusion regarding the needs and preferences of different departments, it is crucial to develop informative materials that promote better understanding. According to Zandin (2001), this could be done by assembling a team of delivery experts, in the corresponding department, to create direct and efficient delivery instructions. These resources could elucidate the specific needs of each department and clarify the purpose behind the requested information, thereby facilitating understanding from the recipients' perspective. This material could be integrated into the on-boarding processes of respective departments and closely monitored for effectiveness.

The suggestion is assigned a "Medium" priority since it is not an urgent requirement. However, implementing this initiative will assist departments in delivering projects on time and ultimately reduce delays in product development and production lead times.

Key affected waste areas: *Underutilized creativity*, *Incorrect processes.*

5.4 Methods discussion

The following section presents a discussion regarding the research quality and the ethical considerations of the project procedures and the aftermath of the thesis results.

5.4.1 Research quality

The research quality of this thesis is evaluated based on the criteria of authenticity and trustworthiness, the criteria and how they were ensured in the project are thoroughly described in Section 2.5 and will further be discussed in this section.

Because the study participants were mostly selected by the supervisors, it may have inserted some bias into the results. However, the bias is most likely reduced due to the snowball sampling and extensive amounts of interviews with different departments and employees. Furthermore, it would be desirable to have had more interviews with the R&D department to ensure authenticity, providing a higher degree of representation from their point of view. Due to the information from R&D being more focused on why the issues occur for MEs', it can be considered to not have an impact on what and where the inefficiencies occur but more serve as a reason for why it occurs.

Through the stakeholder analysis, the information provided by the qualitative data collection has been extensively analyzed to decrease bias and, by that, increase the quality of the research results.

To improve the accuracy and validity of data provided by the VSM, it is necessary to gather additional data points. This can be accomplished by increasing the participation of MEs', performing tests in diverse stress environments of the PLM server, and exploring the impact of unreleased material from input actors on the ME's work process in relation to waste. However, it is important to note that uncovering these factors most likely reveals a more negative situation. Hence, the current result represents the best-case scenario available.

The results from this case study may not be directly transferable to other cases due to its focus on the uniqueness of this particular case. However, the area of research has not been heavily researched, unlike Lean production, as such, it is not unlikely that other companies could have similar situations and apply the proposed methodology to develop their own unique results. The work method was applied to another department at Volvo Cars and proved to be transferable and effective with some smaller adjustments for the different scenarios. The Time Specialist and IT Department welcomed the results with enthusiasm and pointed it out to be valuable input for the improvement of the PLM system.

Looking back, employing an alternative methodology approach could potentially produce better end results, including enhanced suggestions. It is crucial to recognize that each work methodology has its limitations, and the project group has diligently crafted an appropriate approach based on the investigation's profile and initial background information. Consequently, this project adhered to the described method and exercised caution when contemplating any deviations, as doing so would have jeopardized time management and, in the worst case, the validity of the findings.

5.4.2 Ethical considerations

For this thesis, both the procedures of the project and the possible aftermath of the findings can be examined ethically. The thesis purpose of finding inefficiencies in the administration processes of creating PIIs', thus, pinpointing where employees may perform tasks that are unnecessary and not value-adding to their customers. Therefore, emphasis has been put on confidentiality and consent to ensure that no one suffers due to our research. Both the employees being observed and interviewed have been held anonymous to prevent issues from occurring for the individual. Furthermore, multiple employees were observed and interviewed, decreasing the risk of identification through the collected information. Information regarding the thesis purpose, procedures, and questions was described and sent out before the sessions took place to ensure that the employees could make an informed decision regarding their participation in the project.

Based on the findings in this thesis, it can be concluded that different kinds of inefficiencies occur in the administration process of creating PIIs'. There is a possibility that the number of working hours connected to the administration process will be reduced if the proposed solutions (or other solutions developed based on the finding in this thesis) are successfully implemented. The increased efficiency, and gained working hours, can be used by the engineers to focus more on quality-assuring processes. Thus, creating higher-quality PIIs' results in a safer work environment at the plants and increased quality of the products. However, there are risks connected to reducing the administration work, some managers may see it as economically beneficial to reduce the workforce instead of seeing the possibility to increase the quality of their work. Reducing the workforce may also prove to be thoughtless, the organization must secure and maintain its internal resources and competencies because they contribute to the company's capabilities, and if they do not, they may risk losing their competitive advantage.

5.5 Possible impacts of findings

The findings reveal a multitude of inefficiencies across various types and areas in the current administration of Process & Inspection Instructions. The subsequent section delves into the possible impacts of these inefficiencies.

The identified inefficiencies have a significant impact on Volvo Cars as an organization, particularly in slowing down the development process of new cars, risk quality issues with current products, and hindering their ability to quickly adapt to changing customer demands (Lewis & Slack 2014). This is evident in their decision to delay the production of the new EX90 model (Rasmussen 2023). Volvo Cars currently lack the necessary resources and expertise for swift reorganization. The organization is large and is using systems that are overstrained of its intent, referring to their current use of PLM systems. The organization also lacks the standardization of administrative work processes, further impeding its agility and quality risks. In contrast, smaller and more agile organizations with smoother systems and standardization can gain a competitive edge (Lewis & Slack 2014). Without taking immediate action, Volvo Cars risk losing its position as a market leader. Adaptability is especially crucial in today's automotive market, as the transition to an all-electric fleet necessitates significant changes in design and manufacturing processes (Volvo Cars n.d.*b*). Consequently, the company faces the daunting task of restructuring its current workflows. The current strain imposed by the PLM system hampers Volvo Cars' ability to become a more agile company, making it challenging to maintain a strategically aligned organization when certain departments lack the necessary capabilities.

The current turn rate for MEs' is quite high at Volvo Cars. The department's capabilities are diminished when workers seek to leave the role. The company must, as a consequence, invest resources in retraining workers. The reason for the high turn rate could be connected with the psychological factors of the role. MEs', when actively working in the PLM system, feel a high amount of frustration, boredom, and inner stress. Additionally, the time MEs' spend idling represents a financial cost for Volvo Cars, as it does not add value to the customers. Volvo Cars need to put resources into making the situation better, to keep its competence and capabilities within the Manufacturing Engineering department, and to minimize costs.

The absence of standardization and producing faulty services within the administrative processes can have a large impact on Volvo Cars' as a brand (Cova & Pace 2006). The absence can cause quality risks leading to customer dissatisfaction. This can potentially lead to lower order volumes and damage to its reputation in the future. Additionally, poor quality results in rework, placing additional strain on manufacturing and incurring financial costs through recalls.

6
Conclusion

This section examines the project's global impact and assesses the fulfillment of its purpose.

The project has successfully identified specific inefficiencies within the administration of Process & Inspection Instructions, pinpointing their locations within the process. Additionally, the project has formulated improvement suggestions aimed at minimizing these inefficiencies and promoting the production and development of quality-assured products. Consequently, the project has effectively achieved its intended purpose. The study's methodology has been carefully chosen and thoroughly described, furthermore, it has also proven to be successfully applied to other similar cases, ensuring the transferability of the thesis and its approach.

The primary focus of Lean Principles has during the recent decades been on making processes within the factories more efficient and achieving a lean product flow. From our research, it is clear that administrative processes also need to be prioritized, both in the organizations and in research. Processes with physical products in a factory can be easier to analyze for waste than diffuse and intangible products within administrative processes. In a factory, a one-minute stop is easy to see and the costs are more tangible, but in administrative processes, a one-minute stop is seemingly more acceptable even though it still is a cost for the organization. The administrative processes have been partly forgotten in comparison to processes within the factory, the administrative processes have mostly become digitalized but less effort has been on analyzing and making the processes efficient.

There is a pressing need for further research in the field of analyzing administrative processes in order to determine the extent of administrative inefficiency across various industries. More comprehensive investigations need to be executed to provide deeper insights into the pervasiveness and widespread nature of this issue. A thorough exploration of administrative processes can unveil valuable information that enables the development of targeted strategies and solutions to enhance efficiency and productivity in both the public and private sectors.

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A

Seven types of research within Design Research Methodology

Blessing & Chakrabarti (2009) identifies seven types of research within Design Research Methodology. The differences between the types are what kind of study that is performed in the stages. A review-based study is based on a literature review, a comprehensive study is an empirical study and an initial study includes only the first few steps of the stage to prepare results to be used by others and show some of the consequences of the results (Blessing & Chakrabarti 2009). A list of the seven different combinations of studies, identified by Blessing & Chakrabarti (2009), is given below.

Type 1
RC: Review-based →DS I: Comprehensive

Type 2
RC: Review-based →DS I: Comprehensive →PS: Initial

Type 3
RC: Review-based →DS I: Review-based →PS: Comprehensive →DS II: Initial

Type 4
RC: Review-based →DS I: Review-based →PS: Review-based →DS II: Comprehensive →Revisiting PS, either Initial or Comprehensive

Type 5
RC: Review-based →DS I: Comprehensive →PS: Comprehensive →DS II: Initial

Type 6
RC: Review-based →DS I: Review-based →PS: Comprehensive →DS II: Comprehensive →Revisiting PS or DS I, either Initial or Comprehensive

Type 7
RC: Review-based →DS I: Comprehensive →PS: Comprehensive →DS II: Comprehensive →Revisiting PS or DS I: Comprehensive

B

The 14 principles for Lean Administration

An adaption has been made by Larsson et al. (2008) to the original Lean Production principles to better suit administration processes. Larsson et al. (2008) described the principles with several bullet points, giving examples and descriptions of how the principle can be interpreted for administration support processes. The following list is a selection of the bullet points which are of primary interest to this thesis work.

Principle 1. Base decisions on long-term philosophy

- Patients are the key to success, focus on the long-term rather than the short-term and invest in people's development.
- Do not see the implementation of Lean Administration as a quick fix to brighten up the workers or to create a one-time effect to reach savings targets.

Principle 2. Create a continuous flow in the administration support process

- Define and create an efficient administration process.
- Make the process as easy and uncomplicated as possible. Remove all the activities which do not contribute to the customers' needs except those that are required by law, environment, or other value principles.
- Make errors, flaws, and disturbances visible in the process.

Principle 3. Only produce when and what the customer need

- Stop producing reports etc. which is no longer requested.
- Make sure that what is produced is what the customer demands, both for internal and external customers.

Principle 4. Level out the workload

- Producing what the customer wants, at the exact time the customer needs it, can result in workers one week having nothing to do and the other week having to stress and work overtime to finalize the task.
- Level out the workload does not contradict Principle 3, if the planning of delivery and content is done together with the customer.
- Now, does often not mean that a task needs to be completed immediately. By asking, one can discover that it is not as urgent as you initially thought.

Principle 5. Create an administration culture based on that it should be easy to make right and difficult to make errors

- Employees should stop solving symptoms of problems and instead build in quality from the start.
- Encourage employees to find the root cause of problems so they do not reoccur.

Principle 6. Standardize and stabilize

- Standardize the administrative tasks which are needed to fulfil the customers' needs.
- Standardize the administration process sequence and content to manage the specific takt-time.
- Stabilize the process by removing deviations in the input and output.

Principle 7. Visualize so that no problems are hidden

- Use visualization to improve the administration processes.
- Early identification of problems in the process allows one to work proactively with improvements.

Principle 8. Use technology to support the administration processes when they have been simplified

- Use technology and IT as a tool to help and support employees.
- Do not create automatized and complex solutions for inefficient administration processes.
- Simplify the processes before implementing a new IT system.

Principle 9. Nurture leaders who understand the work and live the philosophy

- The leaders are expected to spread and strengthen the culture with Lean Administration every day.

Principle 10. Develop exceptional people and teams

- In order to achieve a better quality of administrative support processes, it is recommended that individuals be entrusted with the responsibility of identifying areas for improvement and implementing standardization and stabilization measures.
- Each individual's understanding of the administration support processes is important for the teamwork to function.
- Teamwork is important, however, the individual performs the value-added work while the team coordinates, motivates, and learns from each other.

Principle 11. Respect your network of internal and external partners and suppliers

- The belief that every department, function, and individual within an organization serves as a provider to either an internal or external customer is a fundamental requirement for succeeding with Lean Administration.

- Help the internal supplier to create and maintain the expected quality if they have issues with providing the correct information.

Principle 12. Go and see for yourself to understand the problem

- A person can never be sure that they understand the issue correctly through reports. One must go and see the issue to understand what is needed to be done.

Principle 13. Make decisions based on consensus

- Involve as many employees as possible in the work for improvements. Acceptance and help with identification can occur with participation.

Principle 14. Create a learning organization

- Create structures which allow for reflection, learning, and continuous improvements.
- A administration support process can only be improved when it has been standardized and stabilized, and then the waste can be eliminated.

C
Interview template

General questions

- Could you describe your role and what it implies?
- How long have you been working in your current position?

Manufacturing Engineering Interview Template

- What information could be missing when creating your PII?
  - What consequences can that cause?
  - How do your handle this situation?
- How do you handle the situation when the model (structure) is not released by R&D?
  - How does this situation affect your work?
- When new information is added, in which part of the PII creation do you need to put the most administration time on?
- How often do you work together with R&D, Tooling, Ergo, and Timesetting?
- For each of the stages (V0, V1, and V2) what takes the longest time to administratively add in the PII?
- How often does the program (TeamCenter) not work as you would like it to work?
  - How do you go about solving the problems that arise?
  - How do you think error messages work today?
  - How often do you get frustrated over these kinds of issues?
- Do you continuously update the PII when new information is added or do you update the PII when the milestone is closing up?
- How long time do you estimate that the picture creation takes for one PII?
- Can you estimate how long time (percentage) you are working administratively with PII and TeamCenter?
- What do you think can be improved in connection with the PI creation?
- Is there any information that you add or adjust frequently that you think could be removed? Alternatively, not update as often?

Plant Engineering Interview Template

- Is there any information in the PII that you rarely use?
- For the different stages (V0, V1, and V2), is there any information that you don't need at that specific time?
- Are there any information that often is updated? And how does that affect you?

- Are there any information that often is missing? And how does that affect you?
- Are there any information that may be faulty at some times? And how does that affect you?
- How are the pictures in the PII used today?
- Is there any information you would need that is not included in the PII today?

R&D Interview Template

- How does the collaboration work with ME today?
- How often do cross-functional meetings occur?
  - Should it occur more often?
- Are all changes documented in CO? Or are there any information that is not included?
- When can conflicts between R&D and ME occur?
  - How do you solve conflicts?
- How does the work process look like? E.g., when you receive information from a supplier that something needs to be changed, how do you handle that kind of information?
- How do you think the VIRA process works?
- How do you work with VPDS?
  - Are milestones followed?
  - What happens when delivery's are late?
- Have you seen the Powerpoint created by ME to help R&D to understand their milestones better?
  - Do you know if it is widely spread among employees at R&D?
- Do you have any thoughts or ideas about how to coordinate R&D and ME better when it comes to deliveries? (Milestones, Release of Models/Structures/Tooling etc)

Business Development Interview Template

- Regarding the logical plan. When and what is ME expected to receive from R&D? As well as when and what is ME expected to deliver to the factories?
- Can you walk us through the process of DPA5? Basic what it means and how it is used
  - What are the main activities?
- How long does it usually take between R&D's milestone and ME's milestone?
- How often do cross-functional meetings take place?
- Is there a work log? (E.g. Kanban board to document what needs to be changed from CO)
- Do you have any thoughts or ideas about how to coordinate the different departments better when it comes to deliveries? (Milestones, Release of Models/Structures/Tooling etc)

D
PII template

PII form TC

Operation												
Type	EL	No	Ref	CC	Operation description	Key Symbols	Work Height	Work Zone	Station no	Variant	TMU	Intro Week
O1	O2	O3	O4	O5	O6	O7	O8	O9	O10	O11	O12	

Structure								
Ref	QTY	Part No	Part Name	Traceability	Variant	CO No	CO Issue	Intro Week
S1	S2	S3	S4	S5	S6			S7

Tool																
Drawing No	Tool Name	Operation	Plant	RPM	Torque [NM]			Angle [Deg]			Gradient Control		Inspection			
					Target	Min	Max	Target	Min	Max	Gradient Shift [%]	Extra Final Angle [DEG]	LCL/ LC PSE	UCL/ UC PSE	LIL/ min PSE	UIL/ max PSE
Tg1	Tg3	Tg5	Tg6	Tg7	Tg8	Tg9	Tg10	Tg11	Tg12	Tg13	Tg15	Tg16	Tg18	Tg19	Tg20	Tg21

Notes
N1

Attachments		
Attachment Name	Modified Date	Type
A1	A2	A3

PL BOP Information		
Effectivity	Type Designator	Plant/Line
PL1	PL2	PL3

PR BOP Information		
Effectivity	Type Designator	Type Designator-ART-Function Group
PR1	PR2	PR3

Revisions				
Effectivity	Change Date	CN Number	Changed By	Reason for Change
Rev1	Rev8	Rev9	Rev2	Rev6

General variant	Title (Description)
H7	H8

Issuer	Issue Date	Intro week	Type	PII no
H9	H4	H3	H2	H1

Figure D.1: Template of Process & Inspection Instruction (PII)

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