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Evaluating and Improving the Efficiency of a Design Change Process

A case study on how a manufacturing company can manage product- and sales structure changes

Master's thesis in Quality and Operations Management

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Abstract

In a world of mass consumption, it is crucial for an organization to continuously improve and adapt its products to meet changing market demands. Having an efficient Engineering Change Management (ECM) process is therefore vital for companies to stay competitive and manage product changes efficiently. The purpose of this thesis was to investigate how manufacturing companies manage product- and sales structure changes in a structured and quality-assured way. The aim was to identify value-adding activities and suggest improvement areas to increase the efficiency of the process. To investigate the Design Change Notice (DCN) process a qualitative case study was conducted at Volvo Penta, including 21 semi-structured interviews. The empirical data was analyzed through thematic analysis and two value stream mappings (VSMs) of the investigated DCN process were constructed to identify waste. Based on the qualitative analysis, it can be concluded that six out of eight types of waste appear directly in the studied DCN process; overproduction, unnecessary motion, transporting, waiting, extra processing, and unnecessary inventory. This thesis presents four improvement areas to mitigate waste and increase the efficiency of the process; system integration and automatization, collaboration and sharing knowledge, standardized change information, and process visualization and role clarification. Further, the study aimed to investigate possible KPIs to measure the value of information, resulting in recommendations of specific measurements for the studied process.

Keywords: Engineering Change Management, Process Optimization, Information Management, Value Stream Mapping, Digital Waste, Performance Measurements.

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Olivia Elofsson & André Virdebrant, Gothenburg, May 2022

List of Acronyms

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

ECM	Engineering Change Management
ERP	Enterprise Resource Planning
DCN	Design Change Notice
GSC	Global Supply Chain
KPI	Key Performance Indicator
PI	Performance Indicator
PLM	Product Lifecycle Management
SOD	Start of Delivery
SOO	Start of Ordering
SOP	Start of Production
VSM	Value Stream Mapping

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1
Introduction

In this chapter, the reader is presented with an introduction to this Master's Thesis. The background to the case study is presented followed by the problem statement and purpose of the thesis. Based on the above, the research questions for this thesis are presented. The chapter ends with an outline of the thesis limitations.

1.1 Background

In a society of mass customization of products, Jokinen et al. (2017) highlights the importance of change management processes to improve products efficiently. The purpose is to avoid unnecessary delays when managing Engineering Change Requests (ECR). In a modern manufacturing industry, information is constantly generated when designing, producing, and delivering products (Madenas et al., 2014). In many cases, the information is managed through IT systems such as Product Lifecycle Management (PLM) and Enterprise Resource Planning (ERP). The ability to manage this change process efficiently sets the foundation for companies to remain competitive and adapt to new market needs (Prasad, 1996; Wu et al., 2014). Likewise, Stekolschik (2016) states that Engineering Change Management (ECM) is a procedure that enhances and supports companies' ability to track, evaluate, and implement product changes based on ideas or solutions. On the contrary, a poor functioning ECM process could lead to additional costs and delays in ECR implementations (Watts, 2011). Further, ECM is considered to be an important tool to prevent waste when managing design changes in complex product structures (Jokinen et al., 2017). Therefore, companies must evaluate ECM and establish efficient processes to manage ECR.

The importance of ECM has increased drastically in modern product development. The reason builds on the increased volume of changes, product complexity, and cost of engineering changes (Kattner et al., 2019). Likewise, manufacturing companies face thousands of ECRs every year (Jokinen et al., 2017) and with increased product complexity, it becomes harder to control product specifications since a single design change could affect hundreds of units (Jaratt et al., 2011). Therefore, it is of high interest for companies to determine the efficiency and measure the performance of ECM. However, it is complicated to perform efficiency analysis of information flows and studies confirm that it is difficult to apply in practice Kolinski and Jaskolska (2018). According to Kolinski and Jaskolska (2018), the main challenge when measuring efficiency is the lack of up-to-date information within the company.

The ECM process builds on information and transferring data between systems and functions can be challenging. The need for cooperative and cross-functional teams is therefore of major importance to maintaining efficient information sharing (Prasad, 1996). Even, if the aspect of information and communication is established, organizations struggle to manage it efficiently (Baan, 2013). According to Baan (2013), inefficient information flows is caused by two factors; an increased volume of internal information and employees not having access to the right data. These two aspects need to be considered to utilize the full potential of information flows. This applies to ECM since a large amount of information is transferred throughout the process. When an ECR is approved, the change information is captured in an Engineering Change Notice (ECN). The purpose of an ECN is to inform other functions about the upcoming change and trigger activities at affected departments (Wu et al., 2014). Several types of waste could appear when information is not shared efficiently in the process Roh et al. (2019). Therefore, it is crucial to investigate how organizations handle ECNs and evaluate possible solutions to optimize internal information flows. In Lean Management theory, Value Stream Mapping (VSM) is often used to identify waste in both material- and information flows (Rother et al., 2004; Pascal, 2015; Earley, nd). Previous research suggests that classic VSM theory can be adapted to digital value streams and recent studies have used VSM for Industry 4.0 (Hartmann et al., 2018). With a similar adaptation of VSM theory, it could be possible to identify and address wastes in ECM processes.

1.2 Case Description

To address the area of information flow optimization, a study was conducted at Volvo Penta. This company is currently investigating its internal ECM process to increase the efficiency and robustness of the process.The investigated case company, Volvo Penta is a manufacturing company that provides world-leading power solutions for marine and industrial use. The company's history goes back to 1868, and ever since, Volvo Penta has been renowned for groundbreaking solutions with great impact on the boating industry. To stay at the forefront of power solutions, a lot of resources are spent on innovative product development, resulting in a large volume of design and engineering changes. All change requests (CR) and the implementation of structural product changes are managed through an internal process referred to as the Design Change Notice (DCN) process. These terms are equivalent to Engineering Change Request (ECR) and Engineering Change Notice (ECN) presented in the previous research.

This case study was initiated by Volvo Penta requesting an evaluation of the company's Design Change Notice (DCN) process. The focus was to investigate activities involving the department of Global Supply Chain (GSC) and give recommendations on how to improve efficiency in the process. During an initial meeting, the process owner expressed the need to have robust processes as the volume of design changes had increased over the last few years. Long lead times, increased workload, and quality deviations are considered challenging in the current process. Further, the process owner also requested ways to measure the performance and efficiency of the process. These parameters established the foundation for this thesis to evaluate how Volvo Penta can improve the efficiency of the DCN process.

1.3 Problem Statement and Purpose

Design changes in product and sales structures entail large amounts of data and information that need to be structured and distributed to different business units. It is a complex, cross-functional process where information is gathered, and transferred between different departments. As the number of design changes increases, so does the need for a standardized, quality-assured, and efficient way of managing such information. Therefore, identifying challenges and areas of improvement to efficiently manage design change structures are of high importance.

The purpose of this thesis is to investigate how manufacturing companies manage product- and sales structure changes in a structured way, by using information management. The thesis aims to identify value-adding activities in the process and provide suggestions on improvement areas to increase information flow efficiency. This includes research on how to measure the value of information and what key performance indicators to use for a Design Change Notice (DCN) process.

1.3.1 Research Question

Following research questions have been determined to reach the aim of this study:

- *What data and main activities are not value-adding in the DCN process of the case company?*
- *How can an organization improve the efficiency of a DCN process?*
- *How can an organization use key performance indicators to measure the efficiency of a DCN process?*

1.4 Delimitations

This thesis investigates how Volvo Penta manages product- and sales structure changes. The main reason is Volvo Penta's interest in the scientific view on the investigated area, and how it can be applied to their business. Therefore, this thesis is limited to investigating a specific company and its process of managing design changes.

The investigated DCN process is a cross-functional process that involves stakeholders from several departments. The ownership of the process lies with the department of GSC and the scope of this thesis was therefore limited to activities affecting GSC. However, all functions involved in the process were examined on a general level to investigate their impact and relations to GSC. Findings on internal processes within these departments are considered secondary input for this thesis. Further, this study focus on product changes that affects the sales structure and is limited to investigating design changes on physical products, since the process to manage software is currently being evaluated internally at Volvo Penta.

1.5 Thesis outline

This section outlines the structure of the thesis with the purpose to support the reader. The thesis is composed of six chapters and the content of each chapter is described below.

Introduction - In the first chapter of this thesis this chapter, the reader is presented with an introduction to the studied area. The background to the case study is presented followed by the problem statement and purpose of the thesis. Based on the above, the research questions for this thesis are presented. The chapter ends with an outline of the limitations of the study.

Theory - The second chapter presents findings from the literature review. First, a brief introduction to Knowledge Management is presented. Second, literature findings on information management are provided. Third, classic information waste from lean management is presented from a digital perspective. In addition, the use of Value Stream Mapping in digital information flows is described to identify waste. Forth, the subject of Engineering Change Management is introduced, including a framework to identify different activities in the change process. Lastly, literature regarding performance measurements is presented together with a proposed framework to determine different levels of performance indicators.

Methodology - In the third chapter, the methodology of the thesis is presented. In the first part, the research strategy is outlined followed by the chosen research design. Second, a brief description of the conducted literature review is defined. Further, a description of the data collection and data analysis is presented, including details on the case study. Lastly, the research quality and ethical considerations of this study are discussed.

Results - The fourth chapter presents findings from Volvo Penta, and two other companies within the Volvo Group. It starts with a presentation of existing process documentation and data retrieved from Volvo Penta, followed by process visualization based upon data extracted from mapping the process. Further, identified challenges and improvement areas are presented. The findings end with a visualization of respondents' aspects of Key performance indicators and how the DCN process appears at other companies within Volvo Group. All data except for the section existing process documentation data are based upon the conducted interviews and one observation.

Discussion - A discussion and analysis of the results are presented in the fifth chapter. It starts with a discussion regarding non-value-adding activities and identified waste in the DCN process. Further, different improvement areas are debated based on indications from the results and previous ECM research. The chapter ends with a presentation of performance measurements used at Volvo Penta compared with recommended KPIs.

Conclusion and Implications - The final part of this thesis presents answers to the research questions, including non-value-adding activities, improvements, and recommended measurements for the DCN process. Further, implications of this study and suggestions for further research are presented followed by specific recommendations to Volvo Penta.

2
Theoretical Background

This chapter presents findings from the literature review. First, a brief introduction to Knowledge Management is presented. Second, literature findings on information management are provided followed by information waste from lean management from a digital perspective. In addition, the use of Value Stream Mapping to identify waste in digital information flows is described. Forth, the subject of Engineering Change Management is introduced, including a framework to identify activities in the change process. Lastly, the theory on performance measurements is presented together with proposed levels of performance indicators.

2.1 Knowledge Management

According to Slack and Lewis (2019); King (2009), knowledge can be separated into two distinct types of knowledge, explicit and tacit. First, explicit knowledge is the most basic form of knowledge that can be stored and shared in definitive forms. For instance, it can be knowledge in the form of instructions or documentation such as process maps received from the organization. Second, tacit knowledge is knowledge earned from experience. For instance, knowledge gained from several years within a specific role or department (Slack and Lewis, 2019). Moreover, King (2009) states that knowledge can be divided into three levels; know-what, know-how, and know-why. Know-what considers what actions need to be performed when managing and evaluating certain information. Know-how considers how to respond to the actions that need to appear and know-why refers to the underlying parameters that motivate the action.

According to King (2009), Knowledge Management (KM) refers to the process of effectively managing systems within organizations to secure that assets are improved and available for all employees. The process involves planning, organizing, motivating, and controlling that people within the organization maintain and increase their knowledge continuously. Assets within KM refer to electronic databases where employees can access information that is relevant to their work. This includes information regarding the organizations' products, processes, and relationships as well as knowledge about ongoing issues and the progress on how to solve them (King, 2009).

Further, Slack and Lewis (2019) mention that the purpose of KM is to stimulate the transaction of tacit knowledge into explicit knowledge. This can be done by transferring tacit knowledge gained by the individual into explicit knowledge that can be reached and applied by other individuals within the organization. These phenomena appear jointly, often through a common platform that supports interaction. An example of knowledge transfer is when certain insights are codified into a common structure or database, to increase the accessibility of knowledge. Likewise, Lupanava (2017) highlights the relevance of KM and its essential role when an organization faces challenges with frequent employee turnover. For instance, lost knowledge when experienced employees leave the organization and fail to transfer their tacit knowledge into explicit knowledge. This creates knowledge gaps and results in challenges when new employees join the team.

To create a platform that stimulates collaboration, knowledge sharing, and interaction between people to maintain knowledge, Slack and Lewis (2019) mention Communities of Practice (CoP) which sets the foundation of KM. CoP's purpose is to manage a common, interactive, and systematic platform of learning when systematizing KM. It collects and connects information to support collaboration when transferring people's tacit knowledge into explicit knowledge. Moreover, joint learning can be used both in live sessions and digital meetings. When collecting information, individuals codify and classify knowledge into common databases. Further, connections appear as a link between codified knowledge bound to the individuals that possess the tacit knowledge. For instance, links to topic experts, knowledge events, or routines of searching for knowledge within the platform. Collaboration appears as a function where further cooperation can be generated, such as communities of practice and cultural support. In conclusion, CoP concertizes KM systems' ability to support collaboration and knowledge sharing (Slack and Lewis, 2019). Likewise, King (2009) states that computer-based communications and information systems can support KM processes. Such a system could involve a platform where documentation and "lessons learned" from previous projects are stored.

2.2 Information Management

Another way to address knowledge is through the hierarchy of data, information, knowledge, and wisdom. The initial theory was presented by Ackoff (1989) who argues that knowledge is retrieved from analyzing and synthesizing information and data. The importance and volume of information in the business world continue to grow exponentially. Having access to accurate up-to-date information has become critical to business success (Wiley and Sons, 2009), and efficient information flow is now a key aspect of decision making(Kolinski and Jaskolska, 2018). To fully utilize the potential of information organizations must develop strategies for information management. Before investigating the purpose of information management one must address the interpretation of information. The term 'information' does not seem to have one widely-shared definition used for business research (Baan, 2013). Instead, a variety of definitions has derived from different perspectives over the last decades. Some information scientists claim that an item of information is a fact that is shared(Madden, 2000), while others refer to it as an influence that leads to transformation (Baan, 2013). It appears that researchers within this area prefer to discuss the concept of information rather than the definition. According to McCreadie and Rice (1999), the concept of information can be divided into four categories: information as a representation of knowledge, information as data in context, information as a part of the communication process, and information as a resource. As a combination of the first two concepts, Wiley and Sons (2009), propose a definition that information is the intelligence and knowledge derived from data. Although the importance of information is established, many organizations struggle to apply and use their information efficiently. Two aspects causing inefficiency in information flows are the increased volume of information generated internally, and employees not having access to the right data. Given these challenges, companies must understand the importance of handling information to utilize the full potential of internal data (Baan, 2013). Hence, information management has become an emerging field within business research (Wiley and Sons, 2009).

The concept of information management has evolved with the development of computer technologies. Starting as the physical control of information and developing to a broader perspective including knowledge management and decision-making. Another aspect of information management includes resources and one of the main characteristics is the use of new technologies, such as artificial intelligence(Boaden and Lockett, 1991). Today, information management can be seen as an infrastructure for how to collecting, storing, and communicating information within the organization. The purpose is to manage and use information with insight as well as create value for individuals and the organization (Editorial, 2021). According to Baan (2013), information should be flowing freely within the organization and continuously being used and maintained. In other words, information needs to be alive to add value to the business (Baan, 2013).

The fundamental principle of information flows is that there is a system with separable parts in which the information passes. It is dependent on the structure of, and relationships in the distribution system, and the process to manage information must be reliable Bremer and Cohnitz (2004). Within the manufacturing industry, information is generated daily when designing, producing, and delivering products. In many cases, this information is generated using a wide range of digital systems such as Product Data Management (PDM), Product Lifecycle Management (PLM), and Enterprise Resource Planning (ERP) (Madenas et al., 2014). The use of different systems has created a landscape, which Madenas et al. (2014) refers to as "Isolated Islands of Information" where information is stored in different silos. This causes difficulties when sharing information across business units. While these systems evolve to support each other through integration, there is often an issue with overlapping information stored in different systems Madenas et al. (2014). It is therefore critical for organizations to develop mechanisms for internal collaboration to fully utilize the potential of information flows. Likewise, Huet et al. (2010), suggest that an interactive and effective bridge between design and manufacturing is required to exchange information in a quality assured way. Likewise, Madenas et al. (2014) concludes that the role of ERP systems is expanding to support manufacturing processes. This is not only achieved by transferring data from one application to another, but rather to integrate key processes in the organization. This adds to the complexity of information flows between systems (Wu et al., 2014). Madenas et al. (2014), argue that having standardized information is essential to achieve a continuous information flow between different departments and systems. They also empathize with the importance of recognizing all systems utilized in the process and identifying integration points.

Creating value for individuals and organizations is an important aspect of information management but analyzing the efficiency of information flows is not a simple matter. Integrated information systems and dependency of the process generate complex issues when measuring efficiency (Kolinski and Jaskolska, 2018). Further, enhancing information sharing is often considered an important aspect of information efficiency. However, according to Madenas et al. (2014) the majority of studies in this area focus on exchanging engineering data between different systems, without evaluating the information's value to the process. Having a structured way of storing information in different systems is fundamental, but does not often contribute to the real value of information (Baan, 2013). In addition, Baan (2013), proposes an alternative approach to measuring the value of information. Instead of focusing on the efficiency of information sharing, he suggests that the focus should be on how information can contribute to the efficient behavior of people working in the process. Moreover, Baan (2013) defines the concept of information productivity as the value added from the efficient use of information. There are four factors that have an impact on information productivity: *availability, accessibility, relevancy,* and *interpretability.* The first factor, availability, can be seen as a fundamental factor of information management. Information needs to be stored somewhere to be managed. Once the availability of information is secured, the next step is to ensure that the information is accessible to the right persons in the organization. Sometimes, information is available in certain systems or silos but not accessible to people in other departments. The lack of easy access to information often results in unnecessary detours to find the right data, which in turn could cause inefficiency in the process. The third factor, relevancy, determines if the information is helpful to the people who have access to it. As an important aspect of relevancy, Baan (2013) highlights the impact that information has on peoples' behavior. Information is considered to be relevant when it supports efficient ways of working and smart decision-making. The fourth and last factor, interpretability, determines if it is possible to make sense of the information provided. People in the process need to be able to scan, understand, and act consequently on the information that they are given. The first two factors are more general and can often be handled by the means of IT, while the third and fourth factors need to be evaluated for each organization (Baan, 2013).

2.3 Information Waste

In contrast to value adding information presented by Baan (2013), waste often occurs due to insufficient information flows (Hartmann et al., 2018). In Lean Management, waste often refers to an activity that the customer is not willing to pay for, and can therefore be seen as the opposite of value (Pascal, 2015). Furthermore, Kleindorfer et al. (2005) highlights that organizations need to decrease operational waste connected to the parameters of time, quality defects, and inventory to maintain competitiveness and become more sustainable. In contrast to waste, information can be seen as a valuable resource in operations management. Even if its value is known as a reliable resource, many organizations struggle to manage information and fail to utilize its full potential (Morin et al., 2021).

According to Roh et al. (2019), information waste can be described, divided, and adapted to the common seven waste of Lean presented by Gopinath and Freiheit (2012) and Hicks (2007). The seven categories of waste are overproduction, unnecessary motion, transporting, waiting, extra processing, unnecessary inventory, and defects. The first category, overproduction, is described by Roh et al. (2019) as waste generated from irrelevant information or data. It occurs when information is not distinct or lacks a clear purpose. The waste of unnecessary motion is generated from a process structure and how employees handle different It-systems when extracting information. Likewise, it considers the degree of working with different and combined systems when extracting information. Waste regarding transportation appears when transferring information between different platforms or media. The waste appears when the information is not transferred on a distinct and transparent path. The fourth type of waste, waiting, is mainly based on consumed time to receive information. For instance, the time it takes to download and extract information from different servers.
Extra processing appears when information in the process needs to be manually edited or clarified. Unnecessary inventory is a waste that considers storing non-used data that is not required to perform activities in the process. The waste often appears when identical data is saved twice on different servers or stored in different forms. The last category of the traditionally seven wastes is defects. Defects consider information streams that are not complete or accurate in sense of incomprehensible information (Roh et al., 2019). In addition to the seven wastes, Verrier et al. (2016); Hicks (2007), mention an eighth parameter that considers losing people's potential. According to Verrier et al. (2016) it refers to the lost potential for improvement. Moreover, it considers people's decreased, or diminished ability to express ideas or creativity for improving a process or practice (Hicks, 2007).

To avoid informational waste, Roh et al. (2019) highlights the need to detect and decrease the affecting parameters which become the root cause of the waste. Likewise, Hicks (2007), align the importance of the seven waste parameters as a tool to eliminate waste, with the purpose to increase informational efficiency within the organization. Further, the seven traditional waste parameters and the additional eighth waste of lean can be considered as strong parameters to work with to reduce waste connected to them (Verrier et al., 2016; Hicks, 2007).

Waste connected to information streams is an ongoing debate, often it is connected to the supply chain with different frameworks and methods to manage potential advantages of efficient information flows. However, there is a lack of research regarding how to analyze the value of information streams. One commonly used tool to analyze informational waste in lean management is value stream mapping (VSM). It is a method that explicitly structures and visualizes information connected to its value-adding activities. Moreover, it gives organizations the possibility to track and evaluate how the stream of information is flowing through different processes (Roh et al., 2019).

2.3.1 Value Stream Mapping 4.0

VSM 4.0 can be seen as an expanded adaption of the classic VSM. The tool allows organizations to process, visualize, and manage all kinds of information in a value stream. It enhances organizations' ability to visualize informational waste through mapping of value- and non-value-adding activities in a digital process. VSM 4.0 was created with the purpose to manage the opportunities of digitalization and integrate information flows by reducing information logistic waste (Hartmann et al., 2018; Meudt et al., 2017). Moreover, Meudt et al. (2017) describes information logistics as the procedure to manage, plan, control, and realization of processing.

According to Hartmann et al. (2018), mapping information flows is considered to be complex and challenging. The reason for complexity builds upon the degree of digitalization and the range of more extensive product variants. To manage the complexity of information flows, it can be divided into a product- and process flows. The product-based flow is strongly connected to product information, such as CAD models and design parameters. Process-based flow is bounded to the activities behind the product information flow and can for instance involve project progress and product status. Generally, process information appears more independent compared to product information.

According to Meudt et al. (2017), the process of VSM 4.0 can be divided into six steps. The first step is to assemble a classic value stream map, to create a basic understanding of the investigated process. This procedure maps all activities to improve a production process in the sense of the classic 7+1 wastes. The second step is to list all storage media used for the recording of data points and KPIs. A storage media can for instance be an ERP system or other programs such as Microsoft Excel. The third step is to collect all data points, and KPIs of the process and connect them to previously listed storage media. The fourth step is to determine the usage of data in the process. By mapping each data point with connections to where the data is being used, it is possible to identify data that has been collected without any direct usage. The fifth step is about defining informational waste in the investigated area. To maintain objectivity, KPIs such as data availability (DA), data usage (DU), and digitalization rate (DR) can be used to visualize the utilization degree of information. The sixth step is to evaluate activities, create an action plan and implement improvements. The improvement activities can be based on the previously mentioned KPIs or bottlenecks in different processes (Meudt et al., 2017).

2.4 Engineering Change Management

Engineering Change Management (ECM) can be described as a coordinating procedure where management tracks, evaluates, and implement product changes based on ideas or new solutions (Stekolschik, 2016). The implementation phase of ECM involves a cross-functional collaboration (Wu et al., 2014), hence, ECM can be seen as a part of concurrent engineering (CE) (Diprima, 1982; Jaratt et al., 2011). According to Prasad (1996), CE mainly builds upon a system that involves a holistic view of integrated product- and process development. The purpose is to develop a total product system that handles every aspect of an organization's product portfolio, for instance, product specifications and change requirements (Prasad, 1996). Moreover, integration of a total product system enables companies ability to react and act faster on customer requirements (Prasad, 1996). Furthermore, Jaratt et al. (2011) support the fact that Product Lifecycle Management (PLM) and Product Data Management (PDM) systems enable the integration of structure and product specifications. Likewise, the systems act as a supportive function when conducting product changes. According to Jaratt et al. (2011), these changes occur through an engineering change (EC), which can be described as a product, or component modification. For instance, it can involve material selections, dimension updates, or product appearance. If a product composition is complex, it is harder to control the structural impact of design changes. This phenomenon is problematic since engineering changes and updates of components need to consider the whole scope of the specific change. Further, it can be challenging to manage ECs if multiple PLM or PDM systems are used in the organization. Therefore, companies should be aware of the number of used systems for the reason that design systems are never fully decomposable and it can create issues regarding dependencies between different systems and parts (Jaratt et al., 2011).

Further, it can seem problematic and challenging to continuously integrate all factors of product changes related to new, and adapted features (Shahin et al., 2017). The CE process manages the overall quality aspects of the products and its process both during the development phase and during changes when reducing lead time and costs. The boundaries stretch over different departments and it can be considered challenging to create cross-collaboration within the CE process. Hence, it can be argued that certain support functions and methods are necessary to decrease the gap between different functions to increase communication, and collaboration (Prasad, 1996). Since the ECM process builds on cross-functional collaboration with multiple departments, it is important to clarify responsibilities in the process. To increase the overall understanding, each department should have clear role descriptions and outline responsibilities within the process (Watts, 2011). Further, Prasad (1996) highlight the need for information modeling, arguing that affected functions need to understand how they communicate with each other. Therefore, planning models which involve design parameters are of great benefit when controlling products in integrated product development processes. The importance of team awareness, communication, and collaboration to manage integration challenges are also supported by Shahin et al. (2017), especially when handling software integration.

2.4.1 ECM Framework

According to Wu et al. (2014), Engineering Change Management constructs the bridge between PLM and ERP systems. The integration of these two supports organizations' ability to fulfill customer demands and find new market opportunities (Prasad, 1996; Wu et al., 2014). Moreover, Wu et al. (2014) states that ERP systems mainly focus on production and manufacturing, while PLM systems focus on design and development parameters. Both sides are integrated through ECM that handles and systematize a total view of a product system. To concretize this process,Wu et al. (2014), suggests an adapted version of the Configuration Management II framework. The original framework is constructed by the Insitute of Configuration Management and provides guidelines to manage products and facilities. The adapted and more advanced framework by Wu et al. (2014) considers the bridge of integrating process domains between design and manufacturing. In Figure 2.1, the different phases of the ECM framework are presented with corresponding activities on the PLM and ERP side.

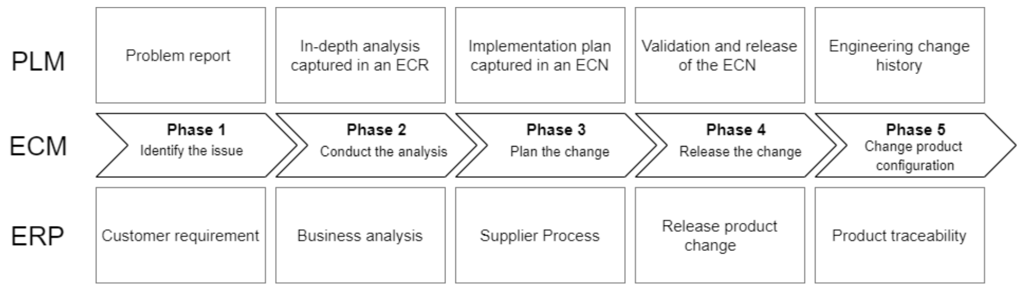

Figure 2.1: Adapted visualization of the ECM framework presented by Wu et al. (2014)

The advanced ECM framework presented by Wu et al. (2014) can be described in five phases, each triggering activities on the PLM and ERP side. Information is constantly processed and transmitted between the two, to move forward with the product change. Hence, the framework considers the whole perspective from product development to sales configuration.

Identify the issue - The first step is to identify issues with existing products. In this phase, customer feedback is collected and analyzed on the ERP side to identify quality issues and customer requirements. Detected problems and improvement suggestions are then sent to the design domain for further investigation. Once the matter has been validated on the PLM side, a problem report, including relevant information on the case, is filed and sent to the change administration for approval.

Conduct the analysis - If a problem report is approved by the change administration an in-depth analysis of the problem will be conducted. This phase results in the creation of an engineering change request (ECR) capturing issues from one or several problem reports. The request can also derive from quality issues in manufacturing or ideas on design changes from product development. An ECR is a document or a transaction file that describes requirements that need to be evaluated for the product change. Based on the ECR, experts within the area of problem control conduct a business analysis on the ERP side, to identify feasibility and product impact based on cost and business justification.

Plan the change - This phase processes a detailed plan to implement the actual change through collaboration with stakeholders in the process. The planning starts on the PLM side with detailed instructions on the change, production plans, and product data structures. Once the ECR has been approved, and all details are established, an engineering change notice (ECN) is sent out to inform different stakeholders about the change. The ECN is sent to the ERP side where a supplier process is initiated to find suitable suppliers and coordinate tasks between internal manufacturing and purchasing. When this task is completed, supplier information is added and the ECN is sent for a final review before releasing the change to the rest of the organization.

Release the change - Once the complete ECN has been approved, the change is released to the rest of the organization. This triggers several activities in different functions. On the PLM side, the product structure and master data are updated based on the given information in the ECN. When all activities are completed the EC as a whole is set up for a final audit to ensure that all data is in place and that the information is clear before the EC is released in the ERP systems. After receiving the final approval, the ERP side administrates the physical implementation in manufacturing and reviews the planned timeline vs. the actual change date.

Change product configuration - The final phases of the ECM framework assess the product change history and traceability. All documentation from the change process is recorded on the PLM side, including technical documentation, cost - and stock analysis, and workflow roles that have been involved in the change. The change history acts as a reference for the ERP side where serial numbers and production dates are added to generate a traceability of the new products.

2.5 Performance Measurements

Measuring performance is a vital part of business improvement as it enables organizations to evaluate if business objectives are being met. Hence, it is important for organizations to be aware of different processes' performance rates. Using performance measurements helps organizations to identify poor performance and potential improvements Lindberg et al. (2015).

There are endless types of metrics that can be used at different levels of the organization, both on a strategic-, and operational level. Some metrics have been derived to maintain a certain level of performance while others are used to improve efficiency (Okes, 2013). However, measuring performance can be considered challenging. Many organizations are working with the wrong measurements or have simply stopped using measurements that were previously established. One common issue is that organizations tend to select metrics based on simplicity rather than the value it contributes with. For instance, to measure whether a task is completed or not, rather than how well it was performed Parmenter (2015). Another common issue with performance metrics is that organizations often use too many measurements, causing managerial overload. This makes it difficult for people in the organization to distinguish what is truly important and information may lose its value. There are also cases where people do not know how to respond to the provided measures. Either they find it hard to read the data, or they are unable to act on the specific situation. It is therefore crucial for organizations to clearly explain the purpose of the measurement, and provide appropriate training to read and understand the data Okes (2013). To mitigate these challenges, it is crucial for organizations to select the right metrics for their business. Both Okes (2013) and Parmenter (2015) stress the importance to link performance measures to strategy, and operational processes. If the strategic objectives are not clear, it is impossible to know what to measure and why. It is therefore important for organizations to understand the involved processes and the purpose of measuring. Parmenter (2015) states that a major part of the work when developing performance measurements lies within the preparations. Lindberg et al. (2015) adds that the purpose of metrics is to create a mutual understanding of the situation and establish a culture that promotes cause-and-effect thinking. When it is time to select metrics on a process and project level, there should be a clear connection to the overall business objectives and structures to different levels in the organization Okes (2013); Parmenter (2015). This is where different kinds of performance measurements evolve.

There are lots of different indicators used to measure the performance of a business, and its processes. Key performance indicator (KPI) is a well-known term in most organizations but it is often confused with performance indicators (PI). Parmenter (2015) explains that KPIs should be considered as measurements that are crucial to the overall business performance. In contrast, a PI is described as a measure to enhance the alignment between the team and the organization's strategy. However, PIs should not be considered less important as it helps improve daily operations. This type of indicator should be non-financial, measured regularly, tied to a team, and focused on a specific activity. In addition, all employees should understand what is required to improve efficiency and be able to act accordingly Parmenter (2015). There is no golden number of metrics that will ensure success for all businesses. It all depends on the complexity and size of the organization Okes (2013). For large organizations,Parmenter (2015) suggest different levels of measurements where the highest level of KPIs should be limited to a maximum number of 10 metrics. In addition, he suggest that an organization could have more than 80 PIs and that the number could vary between departments. Especially in operations management, KPIs have evolved to have a significant role when it comes to evaluating processes and improving workflows. One common KPI used to measure process efficiency in Lean Management is *First Time Yield* or *First Time Through* (Gijo et al., 2014). It measures the number of units that pass through a process without any re-work or adjustments needed (Zhu et al., 2018). Other commonly used KPIs are measures associated with lead time and delays in schedule. For instance, lead time for different phases in the process or downtime in manufacturing. According to (Kattner et al., 2019), useful KPIs for the application in ECM can be derived from these general metrics. In addition, Lindberg et al. (2015) supports that benchmarking KPIs from other, similar businesses is one method of identifying improvement potential. However, Kattner et al. (2016) emphasize the lack of literature covering KPIs specifically developed for, and used in ECM.

In a study of ECM in manufacturing industries, Huang et al. (2003), uses three measures to assess the volume of ECs. The first one is the number of active changes in any phase of the process, excluding suggestions that have been rejected. The second measure is the total time from creation to implementation and the last measurement is active time spent per activity in the process. These measurements are not specifically used as KPIs for the process but rather as an indicator to map the current situation and create an understanding of the volume of ECMs that organizations are dealing with (Huang et al., 2003). However, there are other KPIs used by manufacturing companies to measure the performance of the EC process. According to Lundqvist and Månsson (2013), some commonly used KPIs are: lead time per process step, total lead time, direct runners, punctuality, number of open changes in total, and number of open changes per process step. Direct runners are defined as changes that pass through the process without iteration or downstream adjustments(Lundqvist and Månsson, 2013). In a broader perspective, this data can also be used to identify product categories that are difficult to handle in the EC process. For instance, if the number of rework iterations on a specific product is higher compared to other objects Kattner et al. (2019). In addition, Riviere et al. (2003) mention the number of documents impacted by the EC, and the number of persons involved in the process, as two useful KPIs to measure the performance of ECM.

According to Kattner et al. (2016) metrics in ECM can be identified on four different performance levels, from a general overview to a detailed activity performance. These levels are visualized in Figure 2.2. The highest level, *general performance* includes all types of projects and changes. On this level, the objective is to analyze the role of ECM on a top-level and evaluate how it affects the organization. The second level, *focused performance*, concentrates on a single project to assess the impact that ECs have on the project performance. On this level, it is possible to analyze the required level of resources to handle changes within projects of different sizes. The next level *specific performance* is limited to a certain type of ECs such as quality- or maintenance changes. On this level, it is possible to outline different EC procedures and determine whether a certain type of change is causing issues in the process. In the fourth level, *detailed performance*, the focus is on specific process steps and activities in the ECM process. It is considered to be the most sophisticated level since it allows deeper analysis of potential causes of performance issues. This four-level framework can be used to categorize performance metrics and understand interdependence in the process. Further, Kattner and Lindemann (2017) argues that this framework can be used to choose a level of concentration in the process, an important first step when developing performance metrics in ECM.

By using this framework, Kattner et al. (2019) have identified several indicators for the specific use to assess ECM performance. Some of these measures are the quantity of active ECs, the interrelations between people, and the shortest path of information in the process.

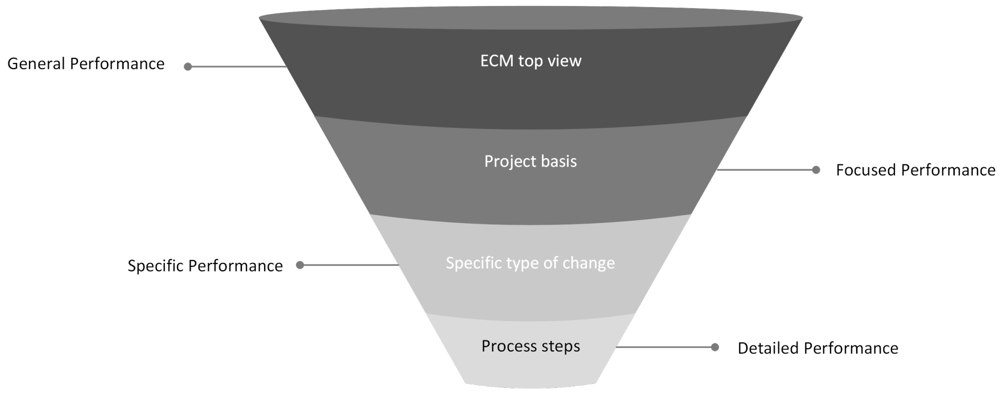

Figure 2.2: Four levels of performance indicators in engineering change management presented by Kattner et al. (2016)

3
Research Methodology

In this chapter, the methodology of this thesis is presented. In the first part, the research strategy is outlined followed by the chosen research design. Second, a brief description of the conducted literature review is defined. Further, a description of the data collection and data analysis is presented, including details on the case study. Lastly, the research quality and ethical considerations of this study are discussed.

3.1 Research Strategy

According to Bell et al. (2019), a Research Strategy consist of the overall approach toward the research area. Likewise, Saunders et al. (2016) align that Research Strategy shall explain how the research questions should be answered and its overall strategy to achieve that. This thesis started with challenges considering a DCN process, received from the studied case company.

Research methods can according to Blomkvist and Hallin (2015); Bell et al. (2019) be divided into qualitative or quantitative methods. A qualitative approach considers the art of data collection, which is based on written and spoken words rather than numerical numbers. This thesis had a qualitative approach and is based on empirical data from deep-focused interviews and existing process information. Using a qualitative method is preferable when addressing complex research areas to capture different individuals' perspectives (Bell et al., 2019). Therefore it was considered a suitable approach for this study.

Further, an abductive research approach was used to conduct this thesis. According to Blomkvist and Hallin (2015), an abductive approach has higher transparency of collected empirical data and connected theory of the area that is investigated. Thus, the relation between theory and empirical data is less strict compared to an inductive and deductive research approach. For this thesis, a more flexible and transparent approach toward existing theory and empirical data within the applied research area was considered to be beneficial. Likewise, Bell et al. (2019) state that abductive business research is often used when the researchers need to involve a "back-and-forth" engagement, considering the authors' preunderstanding of the subject. This aspect was considered necessary for this thesis to remain open-minded when investigating the complexity of information flows and their value-adding parameters.

3.2 Research Design

In addition to the research strategy, a research design is chosen to guide the execution of the research. It provides a framework for collecting and analyzing data that is suited for the research question. Several research designs can be used for qualitative research strategies, one of the most common is the case study design (Bell et al., 2019). This approach is often used in business research, as it provides a bridge between qualitative evidence and deductive research (Eisenhardt and Graebner, 2007). According to Bell et al. (2019); Astalin (2013), a case study focuses on a limited situation such as a single organization, a person, or a single event and is often studied using qualitative methods. It enables in-depth analysis of a unique situation (Saunders et al., 2016), and the goal is to develop a deep understanding of the case and its complexity (Bell et al., 2019). The context of this research is limited to a single process in one organization and using a case study design was therefore considered appropriate for this thesis.

Case studies are often conducted using qualitative methods to collect data, such as observations and interviews (Saunders et al., 2016). Qualitative interviews focus on the interviewee's perspective and are in general more flexible than quantitative methods. For this thesis, semi-structured interviews were used as the main method to collect empirical data. This research method was chosen based on the nature of the studied case, with a clear focus on investigating the DCN process at the case company. Using semi-structured interviews also enables the possibility to make comparisons between the studied case and other companies within the same corporate group.

3.3 Literature Review

A literature review was conducted to broaden the theoretical understanding of the subject. The purpose of a literature review is to understand previous findings relating to the research area, which can help interpret empirical findings (Bell et al., 2019). For this study, several publications related to the research area were reviewed. The following areas were included in the literature review, knowledge management, information management, information waste, value stream mapping, engineering change management, and performance indicators.

3.4 Data Collection

In qualitative research, several scientific methods can be used to collect data, such as document reviews, observations, and interviews (Bell et al., 2019). In this thesis company documents and observations were used to create an overview of the researched area. Further, semi-structured interviews were used to gather empirical data.

3.4.1 Documents and Observations

Participant observations can be described as the process of observing and collecting data through interviews, visualization, and documents of a phenomenon or object that is researched. In this type of observation, the observer can take on different roles with different levels of involvement. One of these roles is *observer-as-participant* where the observer interacts with the participant and asks critical questions during the observation. Hence, the observer can be seen as a detachment that follows and observes the phenomena (Bell et al., 2019). During this master thesis, one observation was conducted through interactive sessions where the researchers observed the work of the DCN coordinator at Volvo Penta. This person was selected for the observation based on their central role and involvement in the process. While the DCN coordinator was performing daily work tasks the researchers asked questions to gain a deeper knowledge of their work procedure. The purpose of the observations was to gather data on how central roles and activities appeared in the limited research area and how they affected the DCN process overall. For instance, observations generated data on what main activities in the process were essential for the DCN coordinator.

In addition to observations, reviewing existing documentation is commonly used in qualitative research. According to Bell et al. (2019), organizational documentation provides case studies with essential background information on the research area. Both in a historical aspect and in a current time frame. Moreover, documentation gives the researcher insight into managerial decisions of why and when certain actions appear. Documentation can be viewed in two aspects, public and private Bell et al. (2019). The documents used in this thesis were private, meaning that only people in the organization had access to the documentation. The material included organizational charts and process maps, which gave information on the investigated process structure, and different stakeholders' hierarchical positions. In addition, company private documents such as emails were used to assess organizational communication between different functions.

When using private documentation in business research it is important to consider challenges regarding credibility. Corporate documentation is most likely reliable and authentic. However, it needs to be evaluated against alternative documents which can be considered more trustworthy or possess a higher degree of credibility (Bell et al., 2019). To manage that, this thesis used Scott (1990) four criteria to evaluate documents: *authenticity*, *credibility*, *representativeness*, and *meaning*. Firstly, *authenticity* involves authorship in sense of fraud. To manage that aspect, every document was checked and controlled by different stakeholders to see if they had different views on the collected document. The second criteria, *credibility*, concerns accuracy of retrieved documents. This was handled by comparing each document's output with relevant scientific literature. This enhanced the perspective of how the documentary described different processes and how the actual processes were. The third perspective of evaluation considers the representativeness of documents' origin. As many of the collected documents were process-oriented, it was challenging to backtrack these documents' historical origins. Therefore, the researchers reviewed these documents critically and compared them with data from conducted interviews. The final criterion, *meaning*, concerns the understanding of the document's purpose, and its readability in sense of language and dating. The objective is to manage accurate interpretation of the retrieved documents. To solve it Scott (1990) mention that textual and content analysis can be considered. During this thesis, the researchers compared the textual meaning of retrieved documents with their content.

3.4.2 Interviews

Semi-structured interviews build on qualitative, open-ended questions that the interviewer uses as a guide to cover specific topics. The questions may not follow a specific order and new questions may be added as the data collection proceeds (Bell et al., 2019). According to Saunders et al. (2016), the benefits of using semi-structured interviews in qualitative research are the flexibility of the process, and the ability to adapt the interview to each situation. In addition, Bell et al. (2019) argue that some structure is necessary to ensure cross-case comparability. The most essential aspect when preparing an interview guide for semi-structured interviews is that the questions focus on the interviewee's perspective and that there is flexibility in the conduct of the interview (Bell et al., 2019). Using open-ended questions is preferable in this case since it allows for the interviewee to express themselves freely. The interview questions were based on the initial understanding of the DCN process and divided into different themes to create structure. The interview guide is presented in Appendix B.

The context of this research is limited to a single organization and interviewees were therefore sampled purposely among employees working with the DCN process. Purposive sampling is based on the research questions and is one of the fundamental principles in qualitative research (Bell et al., 2019). This sampling method is effective only when a limited number of people can serve as primary data sources (Saunders et al., 2016). The sampling was done in consensus with the process owner, to identify key stakeholders with the ability to contribute to a deeper understanding of the case. Sampling size can be problematic in qualitative research since it is hard to tell how many interviews to conduct before theoretical saturation has been achieved (Bell et al., 2019). However, Bell et al. (2019) suggest one guideline for sampling size: the wider the scope, the more interviews will need to be carried out. Since the scope of this thesis is narrow, the sample size is limited to employees that are working with or are affected by the process. To reduce the subjective impact, people from different departments were interviewed. The purpose was to gather perspectives from different business functions and create a wider understanding of the process.

All interviewees were sent a personal invitation where the purpose of the study was explained. The invitation did not include specific interview questions, but the general layout of the interview was outlined. All interviews were held digitally, using Microsoft Teams, to ensure equal conditions for all participants. The interviews were, after the consent of the respondent, recorded to facilitate the transcription.

By doing so, the authors were able to focus on capturing, and understanding the interviewee's perspective and ask follow-up questions instead of focusing on taking notes. The interviews were conducted in both Swedish and English, depending on the preferred language of the interviewee. There are challenges with cross-language qualitative studies, including the risk of misinterpreting data when translating interviews (Squires, 2009). However, since it is the native language of both authors, the benefits of conducting interviews in Swedish were considered to outweigh the risk of misinterpretation when translating to English.

The interviews were conducted in three rounds, starting with the stakeholders at the department of Global Supply Chain, followed by interviews with employees from other departments involved in the process. At least one representative from each of the following departments was participating in this study; Product Development, Purchasing, Manufacturing, Global Supply Chain, Sales information, and Global Aftermarket. The main purpose of these interviews was to map the DCN process at Volvo Penta and capture perspectives from different stakeholders. The third round of interviews was conducted with people from other companies within Volvo Group. In contrast to the interviews conducted at Volvo Penta, only one interview was held at each external company. The people at Volvo Group were selected through the network of higher management at Volvo Penta. The participants were primarily working with the creation and reviews of DCNs with several years of experience in the process. The purpose of the third interview round was to gain a perspective of how Volvo Penta performs in comparison to other companies within Volvo Group. Dividing interviews into batches allows researchers to adjust questions for upcoming interviews and focus on underrepresented topics (Condens, nd).

After conducting all interviews the researchers followed up with specific questions to key persons in the process in order to clarify information when needed. This included clarifying emails and short follow-up meetings. The objective was to generate a deeper understanding of activities from people with the most experienced in the DCN process. The information was also used to verify the value stream mapping of the process and identify potential problem areas. In total 21 interviews with 25 participants were conducted, excluding sessions with the process owner. Out of the total. Five interviews were conducted at GSC, 14 interviews at other departments at Volvo Penta, and two interviews with companies within Volvo Group. The average duration of each interview was 60 min. Detailed information on the conducted interviews are presented in Appendix A.

3.5 Data Analysis

The data analysis was conducted in four steps. The first three steps consider the thematic analysis of the interviews and documents retrieved from Volvo Penta. The fourth step was to conduct two VSMs to visualize the process based on the thematic analysis.

3.5.1 Thematic Analysis of Interviews and Documents

Thematic analysis is a common way to analyze data in qualitative research as it allows researchers to analyze a wide range of qualitative data flexibly. This approach is often used within qualitative research to explore common themes of data between conducted interviews and received information from the studied company (Bell et al., 2019). Importantly, a negative aspect of thematic analysis is that it is based on the interpretation of a specific topic to a higher extent. Hence, interpretation could create bias within the phase of data analysis Saunders et al. (2016). To reduce the potential bias, both authors conducted the analysis and all data was reviewed jointly with thorough discussions. The thematic analysis for this study was constructed on a digital collaboration board to enhance the visualization of a large amount of data. The analysis was divided into three phases, coding, clustering, and identification of relations. These three phases are an adaptation of the thematic analysis method presented by Braun and Clarke (2006) including six steps to conduct a thematic analysis. These six steps are: *Familiarizing yourself with your data, Generating initial codes, Searching for themes, Reviewing themes, Defining and naming themes, and Producing the report.* The three phases used in this thesis and corresponding steps from Braun and Clarke (2006) are presented in Figure 3.1 and described in detail below.

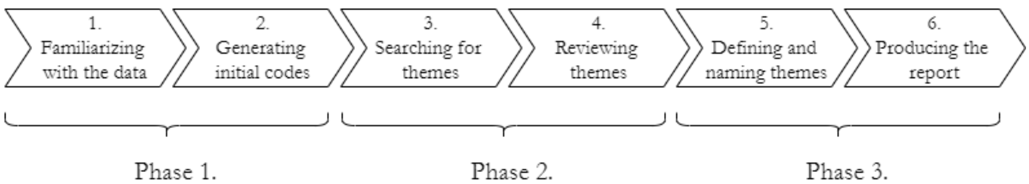

Figure 3.1: Three phases of the thematic analysis an adaptation based on the method presented by Braun and Clarke (2006)

Firstly, all interview transcripts and retrieved documents were summarized and codified to familiarize with the empirical data. Digital notes were created in different colors to differentiate data from different stakeholders and departments. Initially, the data were sorted based on key questions from the interview guide presented in Appendix B. Once all data had been transferred to the digital collaboration board, the authors analyzed each note and defined initial segments to structure the data. The second step of the analysis was to identify themes among the data. According to Bell et al. (2019), there are different criteria to identify a theme such as repetitions of answers, transitions, similarities and differences, and linguistic connectors. Further, the authors reflected on potential missing data that had not been retrieved from the interviews. Where information gaps were been identified, the researchers followed up with specific questions to key persons in the process. Likewise, the authors considered how the interviewed respondents' answers and arguments differed regarding specific topics. Based on these criteria, all data were clustered into different themes and further divided into three main categories: problem areas, improvement areas, and process information. The third step of the thematic analysis was to find relations between the different themes and identify cause and effect correlations. The aim was to identify root causes to identified problem areas and connect challenges with potential improvements. All data regarding process information was segmented to be used as input for the VSM analysis.

3.5.2 Value Stream Mapping

As a fourth step in the analysis, a VSM was conducted to further analyze the data from interviews and documents received from Volvo Penta. The reason was to create a holistic perspective of the process and determine the value of different activities. Data from the thematic analysis was structured by different elements needed in a VSM, such as activities, systems, and transportation. VSM is a Lean tool that originally maps processes from input to output with a lead time for each process step. It is used to identify activities, potential waste, lead time, and backlogs in the process. The purpose of the VSM is to visualize a current state of a value flow combined with its processes of value-adding and non-value-adding activities (Earley, nd; Pascal, 2015; Rother et al., 2004).

In this study, the classic VSM was adapted to digital information flows aligned with the theory on VSM 4.0 presented by Hartmann et al. (2018). Two VSMs were created, one from a holistic perspective, where empirical data was mapped towards the ECM framework presented by Wu et al. (2014). The purpose was to see if Volvo Penta fulfilled certain vital functions according to previous research on ECM. The second VSM focused on the detailed perspective of GSC. The purpose was to visualize and see the current state of the investigated DCN process. Furthermore, the detailed VSM structure was discussed with an external and independent specialist within the area, to ensure that the adaptation was within the limits of VSM theory. This was done to validate the use of VSM in this thesis.

Moreover, the detailed VSM created for this study did not consider cycle time as a metric. The reason builds upon that time stamps for each process step did not exist in the system and was therefore not retrieved during the data collection. Instead, respondents were asked to estimate the time to manage a single, or batch of DCNs to indicate a potential timeline. Moreover, the conducted VSM mapped touchpoints where data was transferred between different functions with reason to see the potential quality deviation of transferred information. For instance, if the same information was sent twice, or if the information was adjusted downstream it was considered a non-value adding activity and waste in the process. All processes shall strive for the highest possible percentage of "first time through" to avoid information waste (Sharma, nd; Ottinger, 2021). In contrast, if the same information was managed directly without the need for clarification and adjustment, it was considered value-adding.

3.6 Research Quality

The three most common criteria for assessing the quality of business research are reliability, replicability, and validity. These criteria are derived mostly from quantitative research characteristics and researchers suggest that other criteria should be used for qualitative research (Bell et al., 2019). For instance, Lincoln and Guba (1985) propose an alternative way of evaluating qualitative studies. They introduce the concept of trustworthiness which is made up of four criteria: *credibility, transferability, dependability*, and *confirmability*. These four criteria were used to evaluate the research quality of this study.

The first criterion, *credibility*, is the most important aspect of trustworthiness in qualitative research (Bell et al., 2019). It refers to the truthfulness of the study and is used to link research findings with reality (StatisticSolution, 2020). There are two main techniques to establish credibility: triangulation, and member validation (Bell et al., 2019). The first technique involves utilizing different sources or methods to collect data. For this study, semi-structured interviews were chosen as the main data collection method, which could affect credibility negatively. However, the data collection included interviews with stakeholders from different departments to generate a broader understanding of the research area. In this study, triangulation of sources was established by utilizing different sources of information within the same method. The second technique to establish credibility is member validation. This is a process where researchers validate their findings by sharing results with the participants. It allows interviewees to review and confirm that their answers have been interpreted correctly. Hence, it allows the respondent to clarify and correct misinterpretation if necessary (Bell et al., 2019).To enhance the credibility of this study, all participants were given access to their interview recordings, transcript, and summaries of the research findings.

The second criterion, *transferability*, considers the ability to generalize findings from the research. The issue with transferability when using a single case study design is that the study is limited to a single situation (Bell et al., 2019). On the contrary, Flyvbjerg (2006) states that findings from a single case study are, to a certain degree generalizable. The transferability of this thesis can be questioned since it is based on a case study with semi-structured interviews as the main method to collect data. However, the purpose of this study is to investigate a specific process at a single company with a focus on understanding the uniqueness and complexity of the case. The intent was not to generalize conclusions to more than this case and transferability was therefore not considered to be an issue for this study. However, this thesis outline some general findings that could apply to other manufacturing companies similar to the studied case company. The implications of this study are further discussed in chapter 6

The third criterion, *dependability*, is used to ensure that the research process has followed proper procedure (Lincoln and Guba, 1985). It is an important criterion since it establishes the consistency and repeatability of research findings. To enhance dependability, all phases of the research process should be carefully documented and reviewed by an external auditor (Bell et al., 2019). To ensure that a proper research methodology has been followed and that the research findings are consistent, this thesis has been critically reviewed by a supervisor at Chalmers University of Technology as well as two opponents.

The final criterion, *confirmability*, refers to the objectivity of research, and findings deriving from it. Although complete objectivity is impossible to establish, it is important that researchers do not allow personal values to affect the study (Bell et al., 2019). To establish confirmability, a detailed method for the collection and analysis of data was outlined at an early stage of the project. As described in chapter 3.5, having a structured method helped mitigate personal bias when analyzing empirical data.

3.7 Ethical Considerations

According to Blomkvist and Hallin (2015), ethical considerations build upon a nuanced praxis regarding scientific behavior, information, consent, utilization, and confidentiality requirements. Therefore, behavior and ethical correctness based upon the authors' research independence were considered. This thesis follows four ethical perspectives presented by Bell et al. (2019); avoidance of harm, informed consent, privacy, and preventing deception.

Firstly, avoidance of harm refers to participants' development of self-esteem, avoidance of stress, harm to career prospects, and negative aspects of future employment. Moreover, the AOM Code of Ethics and Market Research Society Code of Conduct (2014) states that the researchers shall minimize any potential harm to involved personnel participating in a study. The reason builds upon that, interviews possess a high risk of disclosing personal information especially since sample sizes within business or employee research often are smaller (Bell et al., 2019). Therefore, the authors of this thesis have been aware to avoid the identification of responding individuals within the studied case company to maintain anonymity and decrease potential harm. Secondly, to manage the perspective of informed consent, all interviewees received a detailed, written explanation of the interview's purpose and the overall empirical data collection procedure. The purpose was to provide the participants with enough information for them to decide whether to participate in the study. Thirdly, in terms of privacy, the interview invitation stated that all answers will be anonymous to avoid the identification of respondents. The purpose was to ensure that their opinions would not affect them negatively during or after they participate in the interview. The respondents were also asked for recording permission before each interview session to maintain individual privacy. Moreover, all data collected during this thesis was managed and used with confidentiality accordingly to the purpose of this thesis. To enhance these aspects, all recordings were erased after the essential information was extracted. The fourth perspective, deception, refers to when researchers are misleading people by not sharing the true purpose of a study (Bell et al., 2019). It often occurs when participants are not being fully informed and are therefore deceived into participation. To prevent deception, the previous information was repeated before every interview session to ensure that each participant understood the purpose of the interviews.

4
Results

In this chapter, findings from Volvo Penta, and two other companies within Volvo Group are presented. It starts with an outline of specific terminology used in this study. Next, existing process documentation and data retrieved from Volvo Penta are presented, followed by process visualization based on data extracted from mapping the process. Further, identified challenges and improvement areas are presented. The findings end with a visualization of respondents' aspects of Key performance indicators and how the DCN process appears at other companies within Volvo Group. All findings, except for the section on existing process documentation data, are based on data from the conducted interviews.

4.1 Systems and Terminology used at Volvo Penta

To increase the understanding of the results a short description of terminology used throughout the study is presented below. There are two main IT systems used in the DCN process. The PLM system, KOLA, is used to store product information and manage design changes from the department of product development. The main ERP system, E1, is used to manage order books and product forecasts. To set up sales item structure in the ERP system, an additional application called IPA is used. Further, the findings in this study are focused on design changes that affect the sales item structure. These specific types of changes are referred to as K-DCNs within Volvo Penta.

4.2 Process Documentation and Data

Extracted data, received from the DCN log at PD, implied that the number of DCNs has increased over the last years. In the year 2021, Volvo Penta managed and released 2237 K-DCNs. In contrast to the year 2016 when 1413 K-DCNs were released and managed in the DCN process Furthermore, data indicated that the volume of DCN varies over the year, with significant peaks during spring and autumn and lower volumes during the summer. When comparing data over the years, an increasing trend of fluctuations in the volume of DCNs on monthly basis was identified.

The DCN process at Volvo Penta is described in a detailed process map, and additional process description documents. The process map includes information on general activities and visualizes functions and departments involved in the process. Findings showed that specific details of certain activities are missing in the current process map, such as set sourcing when an item is introduced in the main ERP system called E1. Further, the process map does not include information regarding responsible roles for each process step. Some role descriptions were found in other documents including responsibilities and descriptions of certain work tasks. Due to the many activities in the DCN process, findings indicated that the process map was considered to be complex and challenging to understand. In addition to process documentation, Volvo Penta provides education material through a Volvo Group shared training platform. However, the training material was general and not very detailed in contrast to the complexity of the process. There was also documentation from a DCN-game used by Volvo Penta to educate employees. The DCN-game was constructed as a workshop, where all involved functions were invited to participate. The purpose was to increase the holistic understanding of the process and the education was found as value-adding when learning how a DCN flows through the process.

4.3 Value Stream Mapping of the DCN process

The DCN process at Volvo Penta is visualized and described in two different VSMs based on data extracted from interviews, existing process data, and observations. In this chapter, one holistic and one detailed VSM are illustrated and described. The holistic VSM, presented in Figure 2.1 illustrates the DCN process at Volvo Penta in a general perspective adapted to the ECM framework by Wu et al. (2014). The purpose of the holistic VSM is to give a broad overview of the existing DCN process and its current state. The detailed VSM focus on a specific phase of the DCN process from the perspective of GSC.

Within the change organization at Volvo Penta there are different types of design changes. The responsibility for each design change differs depending on the underlying cause of the change. It can be managed through a project group with a Project Manager, a DCN intro block engineer, or individuals responsible for the engine type. The main PLM system used at Volvo Penta and in the DCN process is KOLA. However, there are several sub-systems connected to the PLM- and the ERP system used by different functions. These systems are described in the detailed VSM presented in section 4.3.2.

4.3.1 Holistic view of the DCN process at Volvo Penta

Findings show that activities in the DCN process at Volvo Penta align with all five phases of the ECM- framework presented by Wu et al. (2014) in Figure 2.1. Hence, the general steps in the DCN process are mapped according to the framework and visualized in a VSM illustrated in Figure 4.1. Each process step is described below.

Identify the issue - Firstly, a need for a change appear. The need occurs from one of three cause segments; Quality, Maintenance, or Project. Quality and Maintenance changes are based upon both internal- and external demands. These changes are often based on a quality deviation or maintenance issue at the production plants.

Project-based changes are to a higher degree based on external triggers from customer demands or new innovative ideas from the department of product development. For instance, it can be a new engine combination that the customer desire. However, findings show that triggers for change appear both by internal- and external pressure regardless of cause segment. The information is transferred into their PLM system where the department of product development or a project group identifies the issue and sets up system support in KOLA to follow up on the change procedure.

Conduct the analysis - Secondly, the project group analyzes the change request. Depending on the type of change, different functions get involved in this stage of PD. In many cases, design engineers analyze the change request to conclude whether the change is feasible or not. For instance, if it is possible to construct this new engine combination, or if it is possible to replace an old part with a new one without compromising manufacturing processes. If the change is considered to be feasible, the request is transferred into the planning phase of ECM.

Plan the change – Thirdly, the creation of DCN documentation at Volvo Penta starts with setting up a D-DCN in the PLM system. This is the first initiation of the change where item structure and item numbers are created in KOLA. It also includes CAD drawings and other technical documentation important for the change. The D-DCN is reviewed and sent to purchasing to trigger the process of choosing a supplier. Later, it results in a contract order involving manufacturing to manage material. For design changes that affect the sales structure, an additional K-DCN is created by engineers at PD. The purpose of a K-DCN is to describe changes in the sales structure and transfer the information to other departments in the organization. According to respondents, there are standardized templates that specify what information to include in the K-DCN when creating it in KOLA. The primary scope of this thesis is to investigate K-DCNs. Therefore, further activities involving D-DCN were not considered in the VSM.

Release the change– Fourthly, before releasing the change to other departments outside PD, a review session is conducted. Document specialists reviews and control the change according to standards from the KOLA template. The review appears as a quality gate to ensure that all necessary information is included in the DCN to decrease the risk of rework later in the process. If a K-DCN is approved and released, it triggers different activities at the departments receiving the information. The function of manufacturing prepares for production at specific plants. For instance, plant preparation involves toolsets, instructions, and material logistics. Further, a K-DCN also triggers activities in the department of global aftermarket and sales information. Global aftermarket analyzes the change and prepares the logistics of spare parts. Sales information registers all sales items and sets up the structure in the sale systems. Further, this triggers activities at GSC to transfer the item to the ERP system, collect master data and enable order management. Findings show that these three procedures appear in parallel including some sequential activities that are dependent on other functions. Once all process steps are completed, the manufacturing site is ready for production, all spare parts are available in the aftermarket catalog and the item has been opened for sales.

Change product configuration – the last phase of the ECM framework by Wu et al. (2014), illustrated in Figure 2.1, does not appear as the last phase of the DCN process at Volvo Penta. Instead, findings showed that documentation and traceability of the change is an ongoing activity throughout the DCN process.

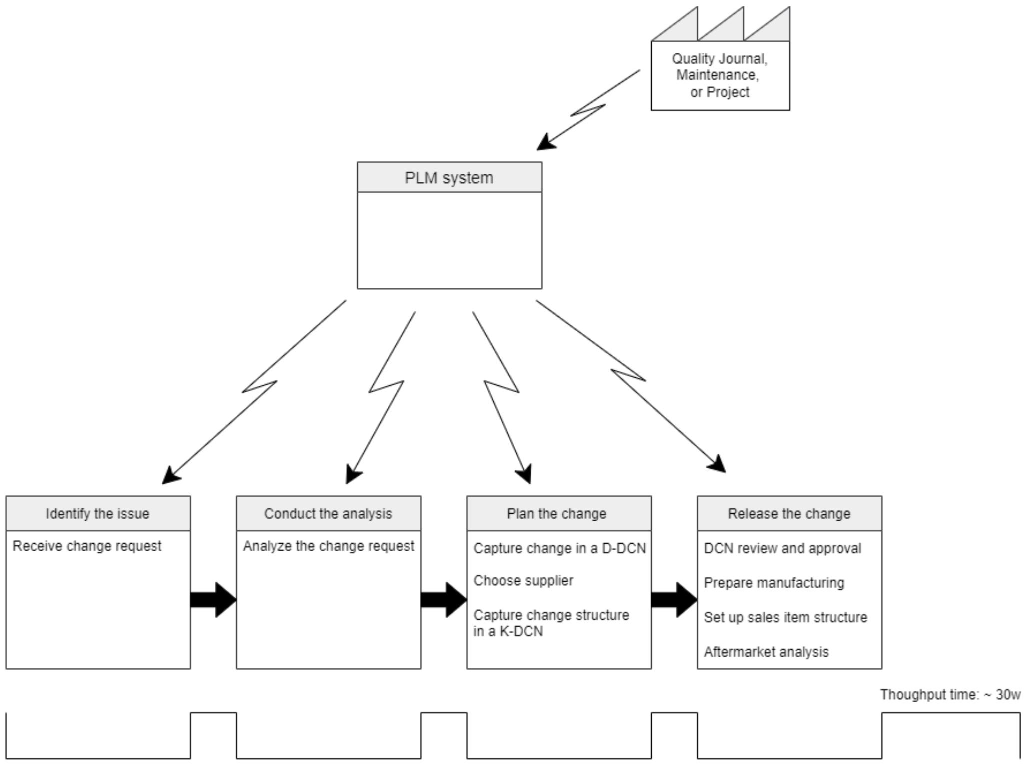

Figure 4.1: A holistic Value Stream Mapping of the DCN process, with activities based on the ECM framework presented by Wu et al. (2014)

4.3.2 Detailed DCN process at Global Supply Chain

The DCN process at Volvo Penta consists of several parallel processes triggered by the same change request. The detailed VSM, presented in Figure 4.2, focuses on the process step *Set up sales item structure*. This process is triggered by K-DCNs and involves several stakeholders in different departments. The process is supported by information from the PLM system used to set up sales item structure in corresponding ERP systems. The lead time for each process step was estimated by respondents during the interviews. In most cases, respondents estimated a minimum and maximum time spent per activity. Hence, two different lead times are displayed for most activities in Figure 4.2. Further, lead time for some activities and backlogs are missing in the detailed VSM, since this data was not identified during the interviews. These lead times were therefore left as unknown, marked with 'XXX' in the figure. A detailed description of empirical data connected to lead time and total throughput time is found in section 4.4. The detailed VSM consists of activities, systems, and backlogs found in the DCN information flow. In addition to standard VSM symbols, dashed arrows are used to visualize communication channels and information sharing between different stakeholders. Green arrows symbolize information that is automatically sent through a system and blue arrows represent communication through Email and Microsoft Teams. Red arrows symbolize unnecessary communication in terms of rework or clarification of information from previous process steps. Below is a detailed description of process steps and activities presented in Figure 4.2

Create DCN - As described in section 4.3.1, a design change can be initiated by three categories, quality, maintenance, and projects. Each initiated change request results in DCNs that trigger activities in different functions. The setup of the sales item structure is triggered by a K-DCN created by design engineers at PD. This type of DCN describes product structure and defines relationships between components, kits, and engine specifications. Standardized templates are used when creating a DCN to ensure that all necessary information is captured in KOLA. Meetings with stakeholders are sometimes held during the creation phase to involve other departments in the upcoming change. The review group, consisting of document specialists, is supporting the design engineers throughout the creation phase. Respondents described it as an iterative process to trim the DCN information before the review process. The lead time to create a DCN varies based on the change characteristics and can also be dependent on the engineer's previous experience.

Review - Once the K-DCN is finalized it is sent to a document specialist for review. The review group receives the information via Email and logs all DCNs in a separate Excel list. The goal is to manage all DCNs within 2 weeks, but according to respondents, the lead time is currently 3-4 weeks. The review process can be divided into three different phases. Firstly, the 2D illustrations and CAD drawings are controlled to verify that all documents have been updated with the new changes. Secondly, the description and structure of the change are reviewed. This includes control of the body text information, object numbers, headings, and other data needed in a DCN for others to understand the purpose of the change. If the information is not sufficient, the DCN is sent back to design engineers at PD for clarification. Once the structural review is finalized, the DCN is sent for final approval. This is the last phase of the review process where certain people need to approve the final DCN version before it is sent out to other departments.

Set up sales structure - Once the K-DCN has been released, information is sent through email to the sales information unit. All incoming DCNs are stored in an internal Excel backlog and distributed to the responsible sales structure specialist who registers the sales item. The item structure is set up in a sales system called PMDM and is based on the DCN information found in KOLA. The red dashed arrow symbolizes additional communication between the departments of sales information and PD when the information in KOLA is insufficient and needs to be clarified in order to proceed. Once the item is set up in PMDM, information is sent automatically to another system called IPA, where GSC proceeds with the next activity. Information is also sent to a second system where the sales structure specialist continues to prepare the item setup in parallel to GSC. For instance, engine specifications are updated to feed the sales system with correct information. These activities are not shown in the detailed VSM but are necessary steps for the process in general.

Set up item in E1 - When the sales item structure has been set up, the DCN is sent to a system called IPA, an application connected to the ERP system E1. All DCNs are stored in the IPA inbox at GSC and are often handled within one week. It is the DCN coordinator's responsibility to create an IPA case for each DCN to set up the item in E1. Some information is automatically populated from PMDM, while other data needs to be manually added based on the information in KOLA. In some cases, information needs to be clarified by engineers at PD or the Supply Chain Planning Manager (SCPM) at GSC. The additional communication is visualized with red, dashed arrows in the detailed VSM. According to respondents, the setup in IPA takes approximately 5 minutes to perform if all necessary data is available. However, some DCNs can take up to several days to complete if clarification or additional information is needed. To follow up on active DCNs, all records from IPA are exported to a separate Excel sheet that is updated once a week. This excel is connected to E1 and is used to track the progress of master data collection and DCN-status. The last step of the item set up in E1 is to set sourcing. The IPA case is signed over to an SCPM who decides what manufacturing plant the item should be sourced from, and if existing components should be used up or scraped. According to respondents, IPA cases are sometimes assigned to the wrong SCPM and need to be reassigned by the DCN coordinator. When the sourcing is completed and the DCN-status has been updated it is time for the next step in the process.

Update master data - Once the item has been set up in E1 it is possible to update product master data. This activity involves stakeholders from three different departments and is administrated by the DCN coordinator. The information is initially sent out by email (Mail 2) and followed up by weekly communication and meetings with all stakeholders involved. First, the responsible prep engineer at the manufacturing site needs to update the cost of all components or products affected by the change. Second, based on the cost, a price coordinator at the department of sales information calculates and updates the price package. Lastly, a custom case manager reviews transfer codes and country of origin for each product together with internal and external suppliers. For each update, a confirmation email is sent to the DCN coordinator to keep track of the progress. Each data entry can also be monitored in Excel since the follow-up list is updated with the latest data directly from E1. The total lead time for this process step varies since each stakeholder is dependent on the previous activity being completed. Further, the lead time depends on the number of items included in the DCN and the type of change. At the shortest, each data update only takes a few minutes. However, it can also take weeks to determine the cost or transfer codes if new suppliers are involved in the change request.

Mail 2 is also sent to responsible demand managers who update demand plans and forecasts for all items involved in the DCN. This activity is not monitored by the DCN coordinator and is therefore not included in the detailed VSM. However, it is an important activity in the overall DCN process.

Control master data - To ensure that all master data is in place, the DCN coordinator regularly controls the progress in the Excel follow-up list. If any data is missing, the DCN coordinator sends reminders to the concerned stakeholder. Since this activity is performed continuously, it is not possible to estimate the lead time for the current state analysis. Once the DCN coordinator has assured that all master data is in place, the DCN is put on hold until the start of ordering (SOO) approaches. In some cases, a DCN can be ready months in advance while others are ready just in time before the items should be opened for sale.

Open item for sales - One week before SOO, the DCN coordinator sends an email (Mail 4) to the department of sales information, confirming that the item is ready to be opened for order. A sales structure specialist then opens the item in ProBuilder so it will be available for customers to order in ProSales. This is done through a system update each Sunday, where all ready items will be opened for ordering the following Monday. Therefore, the lead time to open an item for sales varies from days up to one week.

Update start of ordering - Mail 4 is also sent to the SCPM who updates the final SOO in E1. This date is used to confirm the start of production (SOP) and trigger activities on the manufacturing side. According to respondents, E1 is limited to one SOO for each item regardless of how many plants the item should be sourced from. In some cases, this generates extra lead time since all sourcing plants are restricted to the same opening date.

Update order book - When the final SOO is decided, information is sent to the people at the front office. As a final step in the DCN process at GSC, the Supply Chain Coordinator (SCC) updates all existing customer orders in E1 with the new item numbers. In this process step, the order book can therefore be seen as a backlog until all orders have been updated. According to respondents, the number of existing orders affected by a DCN varies from a few up to hundreds. Hence, the lead time for this activity is difficult to estimate. In some cases, orders have been updated by people at the front office, even though it falls under the responsibility of SCC. This has resulted in a lot of rework and caused confusion according to respondents.

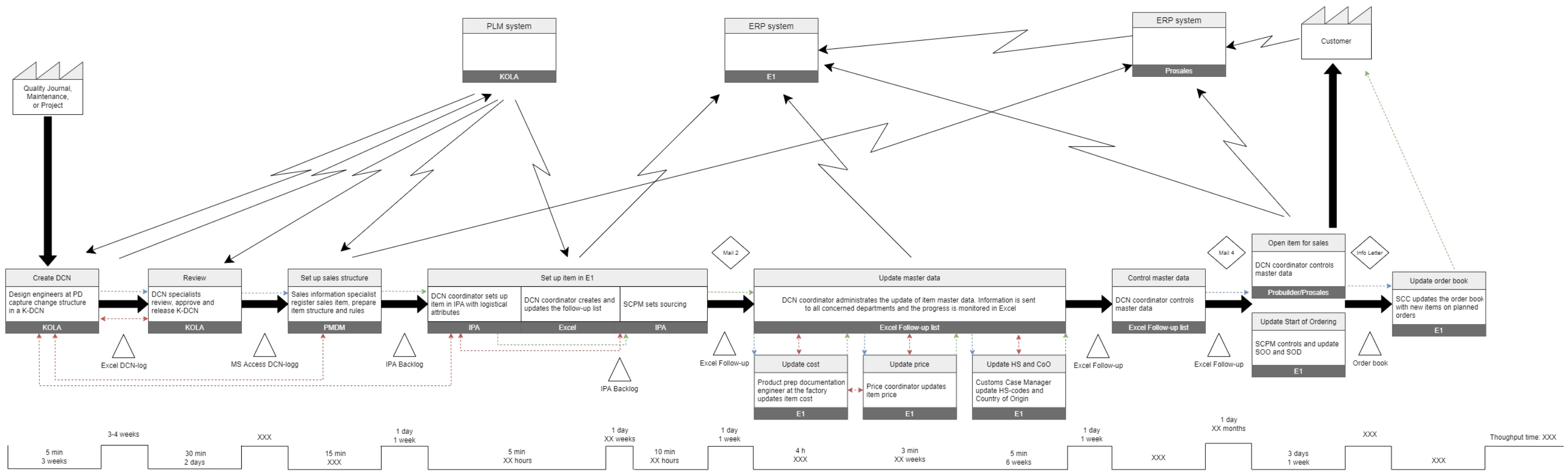

Figure 4.2: A detailed Value Stream Mapping of the process to set up sales item structure, involving activities at the department of Global Supply Chain

4.4 Identified Challenges

During the interviews, participants were asked to describe challenging aspects of the DCN process and specific situations when the process was not optimal. A majority of the challenges were experienced across departments in all steps of the process while others were identified as department-specific issues. Some areas were not directly stated as challenging by the participants but rather mentioned as a cause or effect of other activities. Each identified challenge area with corresponding causes is described below.

Working in Silos - When asked about the DCN process as a whole, only a few employees stated that they had a complete, end-to-end understanding of the process. The reason behind this was explained by years of experience within different functions in the organization. All respondents were able to describe the purpose of the process and DCN activities on a general level. They expressed a great understanding of the process steps within their department and activities performed by the closest stakeholders. To some extent, the respondents also had a decent knowledge of previous and upcoming activities in the process connected to their work. However, most people lacked knowledge of specific activities performed in other departments and agreed that most work is performed in organizational silos. Not having a detailed understanding of the process as a whole was expressed as a statement rather than an issue by most of the respondents. Likewise, working in silos was not necessarily seen as a negative aspect since people at each function are experts within their organizational area. One interviewee stated that *"We need to allow working in silos since the expertise is within the functions. However, we will not succeed if we work completely separate, the functions are interdependent"*. Due to the silo-based work environment, several respondents expressed that they are dependent on others to perform their work. This builds upon the process design where some activities must be performed sequentially. However, several respondents stated that these dependencies did not necessarily prevent them from doing their work as long as everyone completes their activities on time.

Cross functional process - The DCN process involves several departments across the organization and cross-functional collaboration is required to manage activities efficiently. Most respondents stated that it was easy to get in contact with people from other departments and the general impression was that people reached out and offered help if needed. However, multiple activities involving several departments make this process complicated and several respondents perceived the process as complex. Many of them stated that it was difficult to understand the process when they first started working at Volvo Penta. Some respondents argued that it took up to one year to fully understand the activities that they were managing and even longer to get a holistic perspective. A lot of the knowledge was retrieved from experience acquired from implicit learning. All respondents agreed that previous experience within the company is beneficial when working with the DCN process. Due to the long learning period, several respondents stated that the work becomes inefficient when a lot of new employees are involved in the process. At the same time, they were understanding and showed patience when new employees joined the team. Some respondents raised concerns that knowledge gaps might increase when experienced people leave the company since a lot of process information and knowledge has not been entirely documented.

Workload - Based on documentation and raw data from the process, it was established that the total number of DCNs has increased over the last years. This was also confirmed during the interviews as many respondents had experienced an increased workload connected to DCNs. Some respondents stated that the workload was manageable while others, especially respondents from GSC, stated that the workload is currently exceeding 100%. These respondents clarified that the workload varies based on the ongoing projects where DCNs are often released in batches according to the project time plan. Respondents at GCS specifically raised concerns regarding the variation of DCN volume and stated that there was no way to predict when the workload would increase. During the interviews, several respondents commented on the high level of manual work required to perform DCN activities. Most of these respondents referred to manual data entry transferring information from one system to another, or copy-pasting information to excel. One example of such activity is when a DCN is set up in the ERP system, which requires manual data entry with input from several different systems. This was considered to be time-consuming and some participants raised concerns about the risks of human errors.

Missing data and information - Most respondents stated that they had access to all necessary data and information to perform DCN activities. Meaning that data is available in Volvo Penta's IT systems, and accessible to the right people in the organization. On the contrary, several respondents mentioned that DCN information is not always complete and data is sometimes missing. Most of the cases referred to a lack of or unclear DCN information in KOLA. Some respondents stated that the quality of information varied depending on the person writing the DCN. According to respondents at the department of PD, there are standardized templates used when creating a new DCN to ensure that all necessary information is included. However, one respondent stated that *"Even if we follow the template, it's difficult to know if all necessary information has been included"*. Several respondents based these differences on previous experience and process knowledge, claiming that experienced people often know what information is vital to other functions and therefore include it in the DCN. According to other respondents, the right information is often captured in KOLA but the receiving part might not interpret it correctly due to a lack of product- or system knowledge. Another concern raised during the interviews was unclarity regarding SOO, SOP, and SOD. According to some respondents, the different dates sometimes create confusion and misunderstandings as people from different functions refer to different dates. Likewise, there seemed to be a lack of consensus regarding the time between order dates and production dates. According to some respondents, this information is not always available at the beginning of the process and therefore needs to be decided at a later stage.

Information chasing - Several respondents experienced that there is a lot of unnecessary communication when trying to clarify and collect information on a DCN. In many cases, respondents were asked questions outside their responsibilities to which they did not have the answer, or the same question was asked several times. According to respondents, the chasing of information is both time-consuming and creates a stressful work environment. Further, findings indicate that there is a clear connection between lack of communication, missing data, and chasing information. Misunderstandings often occur when the DCN information has not been established with all stakeholders before it is released. Some respondents also mentioned that the lack of visibility in the process entails extra communications in terms of status checkups.

DCN throughput time - Almost every respondent stated that it is impossible to estimate how long it takes to perform each activity in the process. They referred to the wide range of design changes resulting in different types DCNs. Even within the same category of change, the number of affected items in a DCN could vary between 3 and 300 and most respondents answered the question regarding lead-time with *"It depends"*. Some participants were able to estimate a range from minimum to maximum time spend to perform a task. The range often varied between minutes if the respondent had all prerequisites, to weeks if the change required further investigation. When asked about first time though, or direct runners, all respondents agreed that in a perfect scenario, a DCN should run through the process without any disruptions. However, respondents from all departments described situations where information needed to be clarified or an entire DCN needed to be reworked from previous process activities. Some respondents estimated that up to 40% of DCNs needed some sort of clarification. The need to clarify information and additional communication between departments was not considered as rework but rather a natural part of the process. In some cases, rework was done due to human error when manually adding data to different systems. If a DCN is considered to be critical or urgent there are ways to speed up the process. For instance, such DCNs are classified with priority 1 in KOLA to inform other functions that the change is urgent. According to respondents at GSC this prioritization is not transferred to the ERP system and is therefore not used as a guideline in their daily work. According to respondents from Product Development, DCNs with priority 1 sometimes has a longer throughput time than those with priority 2. This is due to the risk of missing vital information when a DCN is ruched through the process, which in turn results in rework. Moreover, respondents from other departments stressed the importance of DCNs being released on time. If a DCN is released too early, it might trigger activities in manufacturing on a change structure that will later be adjusted. On the contrary, if a DCN is released too late, there may not be enough time to perform each activity with high quality. Another factor affecting the total throughput time is the backlogs between activities. Most respondents stated that work connected to the DCN process is only one part of their total responsibilities. Some respondents worked with DCNs daily while others handled DCNs in batches. Since a lot of the information in the process is sent via email to a personal inbox it is difficult to remove these backlogs.

System limitations - When asked about system access all respondents stated that they had access to all systems and information needed to perform their work. However, several respondents from different departments had experienced issues with the IT systems used in the process. Some mentioned concrete system errors that affected their daily work but most of the examples brought up during the interviews had been or will be resolved with ongoing improvement projects. Respondents at GSC specifically mentioned issues regarding IPA, where users need to sign in and out from the ERP system to start the application. In general, people at GSC experienced that this application was not optimal to work in and one respondent stated that *"We still find bugs in IPA that needs to be fixed.* Another concern regarding system limitations was the level of integration. According to respondents, the same information is stored in several different systems, and data is often added manually. While some respondents suggested a higher level of integration as a solution, a few respondents were also concerned about the consequences of integration due to legacy systems. For instance, one respondent stated that systems at different departments do not have the same constraints, making integration more complicated. Another respondent also raised concerns regarding integration based on a previous attempt with an undesired outcome. This situation was also said to affect the DCN process, as the master data structure is built on dependencies between different attributes and system constraints need to be accounted for when a new change is released.

4.5 Identified Improvement areas

The following section describes the respondents' perspectives when asked about improvement areas of the DCN process. These areas were often connected to the challenges identified in the process.

System integration and automation - During the interviews, several respondents claimed that there is a lack of visualization of data in the master data system. For instance, the cost setting procedure from the factory is managed through an excel sheet which only the concerned functions at the factory can access. Likewise, the department of sales information and other connected functions to GSC have their systems where the DCN progress is manually controlled. In these cases, respondents suggest improvement to integrate all functions of different excel lists into one common platform. Accordingly, it would decrease the number of emails and support data overview in the process. Moreover, respondents clarified that different subsystems are already partly connected to KOLA. For instance, some system improvement has increased the automatic data extraction from KOLA into E1 with digital tools. Moreover, there are ongoing projects to integrate information exchange automatically between the different systems to remove additional lists with DCN information. According to respondents at GSC, DNCs from both the marine and industrial segments are currently mixed and hard to separate in the IPA inbox. Respondents suggest that the system could be improved by splitting these segments directly in IPA to avoid misunderstanding. Further, if "Mail 2" was sent automatically by the system after the sourcing was managed it would decrease the workload of certain respondents. However, other respondents were concerned with the risks of system integration. There is an awareness from previous unsuccessful integration projects that resulted in more manual work because it was not functional or efficient. Accordingly, respondents from the department of Parts and Services, stated that an unsuccessful integration project increased the time to perform a certain task by 50%. Further, respondents argued that an increased degree of integration between subsystems and KOLA could be challenging, due to system structure. However, findings show that the extraction of data automatically between systems would enhance the system efficiency and decrease manual work.

Collaboration and sharing knowledge - During the interviews, respondents implied that it is challenging to share, and extract needed data in the DCN process. Information is stored in different sub-systems and separate excel sheets. Therefore, respondents highlighted a need for shared and updated lists with DCN information. One respondent stated that *"Information is just flying everywhere and it is often hard to capture and process everything"*. Likewise, data indicated a need for a broader picture of the direct- and indirect value of information. Different functions need different DCN information to perform activities in the process. Further, in-direct connected functions are not aware of how their work affects other stakeholders in the process. There was consensus among respondents that it is necessary to evaluate how to share information from a more holistic perspective of the process. Moreover, findings showed that respondents have a high awareness of the importance of communication and collaboration in the process. Some stated that system integration and automatizing cannot solve every issue, the process need to involve cross-functional collaboration between departments. Respondents implied that there is a decent exchange of collaboration across departments but it can be improved regarding the accuracy of the shared information. Findings also indicated that the current system makes it hard to track and find correct stakeholders in different departments when searching for information. The complexity of information sharing in the process lies within the variation and type of DCN. To manage the variation, standardized preparatory meetings, similar to project-based DCN meetings, were suggested for K-DCNs derived from maintenance and quality. This procedure should involve a time frame for the DCN release and information on what data is needed by different functions. Even if following-up meetings appear in the current process, they could be more standardized and structured to avoid rework to a higher extent. To support collaboration, respondents enhanced the perspective that strong ownership enhances the responsibility of different activities in the process, which supports collaboration.

Education - In terms of improvement areas regarding education, respondents implied a need for better education in the system KOLA, and the overall DCN process. Training should be offered to new employees as well as existing employees. Respondents argued that courses and education on the process would increase the holistic understanding of the DCN process and its different activities. Further, respondents who had participated in the workshop, referred to as the "DCN-game", were positive about the educational impact. The workshop was held during a development day and all employees were invited to participate. Even respondents with long experience in the process stated that their general understanding of how to manage DCNs increased as a result of the workshop. Further, respondents highlighted that system education in KOLA could decrease the need to clarify information. This implies that employees from other functions lack general knowledge of how KOLA is structured.

Standardized KOLA information - Respondents from all functions clarified a need for an improved standardized KOLA template. Findings implied that DCN descriptions from PD are sometimes challenging to understand when irrelevant or insufficient data is included. For instance, the template should include clarification of business segments and product specifications such as hardware or software. Furthermore, the respondent implied that years of experience do affect the efficiency of the DCN description as design engineers at PD include different information in KOLA. When respondents were asked about potential improvements to solve the variation of information, some implied that DCN information needs to be optimized, more compact, and more concrete. Likewise, it was stated that the body text in KOLA needs to be standardized and include important data such as SOO. Updating the KOLA template would reduce the need to clarify information later in the process. Further, one respondent stated that the standardization should be a collaboration where all stakeholders need to communicate what data they need to have in the KOLA template. Otherwise, it will be challenging to update the template accurately.

Process visualization and role clarification - Most respondents implied that the importance of process visualization is crucial to be able to understand the different activities and current positions when following-up DCNs in general. For instance, receiving suggestions involved an easier holistic overview of the DCN process with each function's activities and actions. Moreover, respondents argued that there is a need for role clarification. One respondent stated that *"clarity regarding what you shall do in your specific role and what fields that should be filled in"*. Findings showed that role descriptions are missing, and the owners need to be enhanced with improved communication. One respondent implied that it is challenging with integration and focus shall rather be on visualization. Another respondent stated *"where does the maintenance responsibility for the whole picture appear, and who has the responsibility to see that all parts work together and do not collide?"*. Further, respondents stated that there is a need for clarified ownership within PD. Further, respondents clarified that there is a responsibility for certain product types, but no one owns the combination or the holistic perspective on it. For instance, hybrids when the hardware is mixed with software.

Release of DCNs and lead-time - When respondents were asked questions about DCN release and lead-time, they stated the importance of DCNs being released at right time. For instance, respondents implied that the countdown calendar should be followed more strictly to avoid urgency in the process. Further, respondents claimed that SOO, SOD, and SOP need to be synced more efficiently to match the change release with the project time plan. Moreover, a respondent argued that DCNs are sometimes released from PD before the change details are complete. Respondent implied that this creates a need for clarification work when the information needs to be added and changed throughout the process. In contrast, one respondent stated that even if the K-DCN is not completed, there is a need to see the structural changes in an early stage. This would ease the work for other departments such as purchasing and project managers. Respondents stated that the lack of capacity in the review process at PD results in longer lead times for the DCN release. Further, respondents implied that the lack of resources might cause quality deviation in the sense of incorrect information on released DCNs. Likewise, one respondent implied that quality deviation often is based on a tight schedule for projects, and argued that information takes time to transfer. One improvement suggestion was to adapt the project plan and account for the transaction time. Further, findings showed that joint planning for all upcoming releases from PD would enhance and support the work of other functions later in the process.

Resource utilization - Respondents claimed that some bottlenecks in the process are caused by lacking capacity in certain departments. Further, findings from the interviews indicated that there is a need for more resources to increase capacity to reduce lead time in the process. Respondents from different departments experienced a high workload due to the increased volume of DCNs and many of them worked more than 100% to manage their work tasks. According to some respondents, the planned workload should not exceed 90% to make time for learning and improvements of the process in general. One respondent stated, “The current structure at Penta, does not include time for personal development”.

4.6 Key Performance Indicators

According to respondents, there are no general KPIs used to measure the overall performance of the DCN process but rather department-specific measurements and internal goals to assess performance. For instance, at the department of PD, a DCN should be reviewed within 3-4 weeks after it has been released. Some respondents were keeping track of the total number of DCNs handled per year, mainly for their interest. In general, most respondents were positive towards KPIs, stating that measurements could be valuable for the DCN process. However, several of them commented that KPIs need to have a clear purpose to add value to the process. Likewise, some respondents raised concerns that KPIs are often not used correctly or tend to lose value over time. During the interviews, previous attempts at applying KPIs to the DCN process were mentioned. One example of such measurement was rating implementation success in the factories. Some participants considered this ranking to be a subjective assessment and the trustworthiness of the metric could be questioned. Another example was the attempt to measure how often rework was required based on mistakes in the process. However, this KPI was considered challenging to measure and interpret. According to one respondent, it was not possible to distinguish rework due to mistakes from rework due to changed project conditions.

During the interviews, several respondents proposed potential KPIs that could be used to measure the performance of the DCN process. Some of these suggestions were not considered to be typical KPIs but rather general measurements that could help clarify the holistic perspective of the process. Tracking lead time for each process step was one of the most common suggestions discussed during the interviews. Several respondents stated that having a correct throughput time for different types of DCNs would ease the project planning and thereby improve the punctuality of the process. Currently, the planning is based on estimated lead time for different project sizes and does not consider different types of design changes. Other respondents raised concerns about using lead time as a KPI. They claimed that the focus should not be on reducing the lead time as it might affect the quality of a DCN. Another measurement addressed during the interviews was the volume of active DCNs in each process step. This measurement would help employees to predict the number of incoming DCNs and thereby manage the workload.

4.7 The DCN process at other companies within Volvo Group

The DCN process used at the two studied companies A and B, within Volvo Group, was described as similar to the one used at Volvo Penta. One of the participants explained that the overall purpose, to implement a design change, is the same even though single activities may differ. In both companies, a design change is released from product development and the structural changes are captured in a K-DCN. The change is reviewed before approval which then triggers activities in other parts of the organization such as operations and aftermarket. Since the two companies are a part of the same corporate group as Volvo Penta, the core PLM system, KOLA, is primarily used to handle DCNs at both companies.

Company A - A description of the DCN process at company A was included in the general management manual for the company. During the interview, the respondent showed how to navigate the manual to get information about each process step. However, the respondent also stated that this tool was not exclusively used for the DCN process and detailed activities were not included.

At company A it is the design engineer who is responsible for writing the K-DCN and the document specialist is responsible for reviewing and approving it. According to the respondent, it is an iterative process where document specialists are supporting design engineers before a K-DCN is released. The respondent also stated that a certain level of product knowledge is required to create a sufficient DCN, knowledge that most people obtain from years of experience within the company. At company A, the names of all stakeholders affected by the change are included in the DCN body text in KOLA. Before releasing the change, all stakeholders should be contacted to facilitate the change and ensure that all functions have been informed. After a change has been released, a product architect is responsible to control master data and update the order system. When asked about system support the respondent explained that there are several systems used throughout the DCN process at company A, which includes a lot of manual data entry. Even though a higher degree of system integration was requested the respondent also stated that no system can eliminate all errors. According to the respondent, company A handles approximately 4500 K-DCNs per year and the number has been relatively stable over the last three years. The respondent estimated the throughput time for a K-DCN to be 12 weeks but the aim is to release a structural change approximately 1 year before SOD. There are currently no KPIs used to measure the efficiency of the DCN process at company A. Instead of using KPIs the respondent suggested looking at trends over time to evaluate the process. It was also stated that KPIs should not be connected to incentives such as salary or other personal gains.

Company B- At company B, it is the document specialist who writes the K-DCN and ensures that necessary information is included. This procedure differs from the other studied companies, where the design engineer creates DCNs. According to respondents, this division of roles was made to increase the quality of DCN descriptions in KOLA. This requires close collaboration between product development and the document specialist before a DCN is created. When asked about DCN quality, a respondent stated that the given information is sometimes inadequate but the overall collaboration works well. Further, the respondents stated that most engineers have a close collaboration with stakeholders in other functions, such as manufacturing and aftermarket. The holistic perspective and general understanding of the process were considered to be based on previous experience within the organization. At company B there is no available process map specifically developed for the DCN process. Instead, the respondents referred to the general project handbook. The review process at company B is divided into two phases. First, all involved functions, including manufacturing, review, and approve the change before sending it for a second review and approval by the product owner or higher management. After the change has been approved the K-DCN is released to the rest of the organization where operational activities are handled by another company within Volvo Group. At company B, several systems are used in the DCN process and the respondents requested system integration to minimize the manual work and reduce the risk of entering incorrect data into the system. To educate new employees, company B has special training programs for the DCN process and specific systems that are used.

The respondents were only able to estimate the number of K-DCNs handled within their specific segment, around 3000, but the total number of K-DCNs for company B was unknown. According to the respondents, the throughput time for a K-DCN varies but the aim was to release a K-DCN 1-2 years before SOD. When asked about KPIs, the respondents confirmed that no KPIs were currently used for the DCN process at company B. A previous attempt to measure punctuality in the process was made, to control if a DCN was released on time or not. However, as one participant expressed *"Since the release date was adjustable this KPI was pointless"*. The respondents also raised a concern regarding KPIs losing value over time and that KPIs should serve a clear purpose.

5
Discussion

In this chapter, a discussion and analysis of the empirical findings are presented. It starts with a discussion regarding non-value-adding activities and identified waste in the DCN process. Further, different improvement areas are debated based on indications from the results and previous ECM research. The chapter ends with a presentation of performance measurements used at Volvo Penta compared with recommended KPIs from previous ECM research.

5.1 Non-value adding activities in the DCN process

The DCN process at Volvo Penta is primarily following the steps in the ECM framework presented by Wu et al. (2014). The deviation is mainly regarding the last phase, Change Product Configuration, where the change is documented for traceability including cost analysis and serial numbers. At Volvo Penta, these tasks are conducted in parallel throughout the process, and not as a final step after the change has been implemented. Moreover, considering the aspect of how data is transferred between the PLM and ERP system at Volvo Penta, it can be argued that Volvo Penta's current DCN process is functional and fulfill the purpose to satisfy customer demand and find new market opportunities. Likewise, the structural changes investigated in this study, considering hardware, which is aligned with Prasad (1996); Stekolschik (2016); Wu et al. (2014) purpose of ECM.

The two studied companies within Volvo Group followed a similar DCN process as Volvo Penta with some differences. For instance, Company A possesses similar process maps and descriptions over their DCN process. In contrast, Company B did not have a classic process map or description of the DCN process specifically. Instead, they relied on the corporate project handbook that includes some information on when to release DCNs based on decision gates. Even though company B lacked a detailed description of the DCN process, the process steps described during the interviews were similar to the ones mentioned in Wu et al. (2014) ECM framework. The greatest contrast compared to Volvo Penta was that Company B uses a document specialist to create the DCN in KOLA instead of a Design Engineer. It can be argued that this appears more proactive to avoid waste as overproduction according to Roh et al. (2019), since the document specialist is an expert on how to manage documentation in KOLA. Likewise, it can be argued that the Design Engineer is not objective toward the holistic perspective of how a DCN affects other functions and what data is relevant to include. Findings from Volvo Penta showed that the variation in DCN information is based upon the degree of previous experience and organizational knowledge. There are benefits to using both approaches mentioned above, and this study does not indicate that one solution is superior to the other. Instead, it can be argued that the differences when creating a DCN are mainly based on different organizational structures. Moreover, due to the limited sample size, the interviews with companies A and B were focused on the creation and review of a DCN rather than GSC or operations. Therefore, it can be argued that these findings appear biased compared to findings at Volvo Penta.

5.1.1 Identified waste

According to Baan (2013) information needs to be alive in order to add value to a business organization. Likewise, the information should continuously flow, be used, and maintained throughout the process. Based on empirical findings, that is not always the case in the DCN process as several bottlenecks were identified. For instance, information is stored in different backlogs resulting in disruptions in the information flow. Kleindorfer et al. (2005) states that organizations need to decrease waste connected to time quality, defects, and inventory to remain competitive. Therefore, it can be argued that there is a huge benefit to optimizing internal information flows such as the DCN process and removing parameters that create waste.

Referring to the detailed VSM presented in section 4.3.2, Figure 4.2, and identified challenges presented in section 4.4, several non-value-adding activities were identified in the DCN process. Non-value adding activities can be divided into seven different wastes presented by Gopinath and Freiheit (2012); Hicks (2007); Roh et al. (2019) including the additional eighth waste presented by Verrier et al. (2016); Hicks (2007). From the analysis of the detailed VSM, six out of eight wastes were directly identified in the process; overproduction, unnecessary motion, transporting, waiting, extra processing, and unnecessary inventory. Simultaneous, the waste of Defects and Losing people´s potential appeared as indirect effects of the waste parameters mentioned above.

Overproduction – Respondents argued that a lot of the information shared in the DCN process was irrelevant or unclear, and sometimes, the necessary data was missing in KOLA. This results in a lot of unnecessary communication between different stakeholders to clarify information in several process steps. Further, It can be argued that these events trigger a chasing behavior among employees when they need to clarify or process the information. The need to interpret a lot of information prolongs the total throughput time for a DCN and could harm the quality of information. According to Roh et al. (2019), information needs to be distinct with a clear purpose to avoid overproduction. For the DCN process, this applies to the DCN description in KOLA which needs to include detailed information without adding irrelevant data.

Unnecessary motion - Email is the primary communication channel when sharing internal information in the DCN process. Respondents claimed that a lot of information needs to be clarified to manage different activities which can be classified as unnecessary motion. This waste appeared mainly in the process step of updating master data since this step involves several stakeholders in other departments. However, this type of waste was also detected in the other parts of the process. The waste of unnecessary motion appears when stakeholders need to send clarification emails back and forth in the process to maintain the progress of the value stream. It can be argued that knowledge of how employees extract data is crucial to maintaining efficiency within information flows. Stakeholders in the DCN process use different methods when extracting the same data, which indicates that there is a lack of a standardized procedure for handling information in different IT systems. Likewise,Roh et al. (2019) mentions that waste within this category appears from process structure and employees' ability to handle different IT-system when extracting information. This applies to Volvo Penta since several respondents mentioned challenges when extracting information from and between different systems. For instance, different excel sheets are used to extract information from IPA and E1. Likewise, respondents implied that KOLA templates were not followed by everyone, indicating that stakeholders have different work procedures when creating a DCN. Therefore, it can be argued that waste appears when extracting and interpreting data received from different stakeholders, based upon unstandardized procedures of collecting and extracting information. It can be argued that this waste connects to the waste of overproduction in sense of the need for distinct information with a clear purpose mentioned by Roh et al. (2019). Further, Roh et al. (2019) also states that waste within this category is generated based upon the degree of working with different, and combined systems when extracting information. It can be argued that the more systems a company use to manage a process, the higher risk of unnecessary motion. At Volvo Penta, there are multiple systems used in the DCN process generating waste in most process steps. Therefore, a need for standardized work procedure and process structure is essential to avoid waste in sense of unnecessary motion.

Transporting – Information in the DCN process appears in several forms in different systems. For instance, product data and change information are stored in KOLA, Excel lists, and different web-based SharePoint. During the interviews, a respondent stated *"Data is flying everywhere, and it is often hard to capture and process it"*. According to Roh et al. (2019), waste in the sense of transportation appears when data is transferred between different systems or media platforms. Likewise, this waste appears when information is not transmitted on a direct path. It can be argued that this waste is closely connected to the waste of unnecessary motion and its aspects mentioned above. The IT infrastructure at Volvo Penta has developed over several years, resulting in multiple systems used in different departments. Based on the empirical findings, some level of integration has been incorporated into the DCN process. However, in several process activities, employees are manually transferring data between different systems. It can be argued that this does not only affect the lead time but also increase the potential risk of transferring data incorrectly. Empirical findings indicate that some systems are more atomized than others. For instance, some data is automatically transferred between PMDM and IPA as described in the detailed VSM. Furthermore, digital information stored in different DCNs is increasing and data storage strategy will become an important area for Volvo Penta to consider. The digital infrastructure of how to collect, store, and communicate information efficiently is of high importance for the DCN process. The purpose is to avoid waste of transportation and increase the efficiency of the information flow. Likewise, it can be argued that increased integration between systems also decreases the waste of transportation.

Waiting – The waste of waiting, is according to Roh et al. (2019) the time it takes to receive information. In the case of Volvo Penta, this waste appears mainly in the process step of updating master data, since it is a sequential process involving stakeholders from different departments. For instance, product price cannot be calculated before the cost for each component has been uploaded and HS codes are entered once all other master data is in place. This type of waste can appear internally while waiting for other functions to finalize their activities, but it could also be connected to lead time for external suppliers. For instance, the process of collecting HS codes from new suppliers could take several weeks resulting in unnecessary stand-by in the process. This results in a lot of waiting and extra communication which in turn affects the total lead time for this process step.

Extra processing – The waste of extra processing appears information or data needs to be manually edited Roh et al. (2019). During the interviews, respondents claimed that several activities in the DCN process require manual editing of information and data. The lack of system integration and insufficient excel tools are factors contributing to the waste of extra processing. Likewise, findings imply that manual work makes the process inefficient and increases the risk of adding the wrong data. In contrast, findings also indicated that manual work enhanced the feeling of control for some employees. However, in terms of extra processing, manual editing is always considered to be a waste. A high level of manual editing could also result in longer lead times for each activity compared to automatic data transfer. The current process is built upon manually transferring data to different systems, which makes it challenging to avoid extra processing. Further, it can be argued that this waste closely appears as an indirect consequence of unnecessary motion and transporting.

Unnecessary inventory– According to Roh et al. (2019), the waste of unnecessary inventory appears when identical data is saved twice in different systems or stored data that is not used in the process. The process structure at Volvo Penta includes multiple systems where information is stored in both PLM and ERP systems. Based on the detailed VSM, unnecessary inventory appeared in several steps of the DCN process. Hence, it can be argued that a lot of waste is generated when data is transferred between different systems to manage design changes. Findings indicate that the main reason for storing data twice is limited system integration and challenges connected to legacy systems. The waste of unnecessary inventory is connected to the waste of extra processing required when manually adding data in several systems.

Defects and *Losing people's potential*– According to Roh et al. (2019), defects appear when information streams are not complete or accurate in sense of incomprehensible information. In this study, empirical findings did not identify any direct causes of defected information streams in the DCN process, but rather as an indirect consequence of unnecessary inventory, extra processing, and unnecessary motion. Even if the DCN process appears complex and challenging, findings indicate that the process is comprehensible, complete, and functional with enough information and systems to maintain a constant flow of information. It can be argued that the process fulfills the purpose to handle structural design changes and share information in DCNs even if different types of waste have been identified. Likewise, Losing people's potential appears as an indirect effect of all waste described above. According to Verrier et al. (2016); Hicks (2007), it refers to the lost potential for improvement when people's ability to express creative ideas decreases. It can be argued that the waste of losing people's potential appears as a side effect of other wastes in the process. For instance, when employees need to spend time on extra processing and manual editing of data, the time to elaborate on improvements decreases.

5.2 How to improve the DCN process

As presented in section 4.4, several challenges in the DCN process have been identified from empirical data. Some of them can be classified as digital waste, while others are factors from the complexity of the process. Based on literature and empirical findings, there are several ways to reduce the impact of those challenges and improve efficiency in the DCN process.

5.2.1 System integration and automatization

The use of multiple systems throughout the process entails a lot of manual work when transferring data and information between different media. Storing information in different systems is a common challenge for companies worldwide, and Madenas et al. (2014) refers to it as *'Islands of information'*. Not only is it time-consuming to add data manually but it also increases the risk of human error. Using multiple systems enhance the risk of storing the same information twice, creating unnecessary inventory in the process. As discussed above, transferring information is considered to be one of seven wastes according to Roh et al. (2019). This waste could be reduced by integrating and automating the systems and media used in the process. Further, empirical findings indicate that manual work, unnecessary communication, and system errors were common challenges in the process, especially in activities performed at GSC. Some of these wastes would be reduced by further integrating the PLM- and ERP systems. For instance, if data would be automatically fetched from KOLA the lead time for setting up items in E1 would decrease drastically. This argument is supported by Wu et al. (2014), who states that ECM should be the bridge between PLM- and ERP systems, and Madenas et al. (2014) who stress the importance of system integration to utilize information efficiently.

System integration could also increase information productivity in the process, in terms of data availability and accessibility (Baan, 2013). According to respondents, data availability and accessibility were not considered to be an issue in the DCN process. On the contrary, some respondents stated that information is owned by other departments which sometimes creates issues with the data structure. In those cases, information was available somewhere, but not accessible to the right person. Hence, system integration could enable accessibility, increase information productivity, and decrease the negative aspect of information silos mentioned by Madenas et al. (2014). Further, there are always risks when integrating multiple systems, especially when the systems have been modified to fit department-specific needs. This concern was raised by a few respondents who had previous experience with unsuccessful integration projects. However, there are minor changes in terms of automation and visualization that could benefit the DCN process, without risking integration issues. One example could be automatizing Mail 2 by sending out notifications from IPA instead of sharing information via email.

5.2.2 Collaboration and sharing knowledge

Empirical findings indicate that working in silos diminished the holistic understanding of the DCN process. On the contrary, respondents implied that it has to be a certain degree of silo-inspired work in the DCN process since the expertise lies within each function. Likewise, Madenas et al. (2014) states that it is common for companies to have informational silos in processes where information is stored both in PLM and ERP systems. This indicates that it is challenging to share information and knowledge between different functions when working in silos. It can be argued that working in silos is efficient when performing a task to maintain focus but platforms for collaboration, and information sharing become crucial to decrease the negative aspects of silo-based work.

To increase knowledge sharing in organizations, Slack and Lewis (2019) states that it is important to build a common platform to enable collaboration. In the case of Volvo Penta, collaboration appears in meetings, both live and digitally, with several stakeholders present. Even though information and knowledge are spread on different media platforms it seems to be inefficient. Findings implied that some necessary data and information were difficult to find and process. In these cases, missing information was mainly based upon un-complete or missing data in KOLA. Also, respondents claimed that it is challenging to understand how the DCN process connects to direct and indirect stakeholders and their need for data. It can be argued that an improved joint platform, where different functions collaborate through workshops or weekly brainstorming sessions, could be beneficial to manage the negative aspects of information silos. Likewise, these sessions should appear in a creative environment to stimulate interaction and problem-solving. It can be argued that a jointly developed learning platform could enhance the degree of collaboration and decrease quality deviation within the DCN process. Further, Madenas et al. (2014) argue that information needs to be structured, and standardized to support a continuous information flow between different departments and systems. Hence, the output of this platform for joint learning needs to be available with clear instructions to invite learning and information sharing. Additional to this joint platform it is important to provide employees with proper training. As respondents mentioned, a DCN game has previously been held at Volvo Penta where stakeholders from concerned departments followed a DCN through each process step. It can be argued, that this type of workshop is an appropriate way to further educate and maintain knowledge of the process.

Further, findings implied that the correctness of data can be derived from years of experience and process knowledge within Volvo Penta. Lupanava (2017) stresses the importance of KM to avoid knowledge gaps caused by frequent employee turnover. Moreover, the purpose of KM is to avoid the failure of transferring tacit knowledge into explicit (Slack and Lewis, 2019). It can be argued that the outcome of information, its accessibility, and its accuracy seems to be the product of years of experience within Volvo Penta. Indicating that, the fewer years of experience within Volvo Penta, the higher risk of inaccurate DCN data and information. Therefore, it can be argued that KM fulfills an important function when minimizing knowledge gaps when new employees join an organization. To avoid certain risks connected to employee turnover and employees lacking experience, information sharing needs to be standardized to a higher degree.

Moreover, empirical data implied a need for preparatory DCN meetings to avoid misinterpretation of information. By involving all stakeholders in an early stage of the process, waste connected to rework and clarification could be reduced. For instance, set up pre-preparatory meetings with concerned functions considering specific DCNs where involved stakeholders can discuss ideas, challenges, and different needs to manage the DCN. It can be argued that such meetings would enhance information and knowledge sharing, and result in higher collaboration. To increase efficiency, these preparatory meetings should be standardized with a clear agenda. For instance, by a using standard template for each meeting that is based upon DCN type or the three cause segments project, maintenance, and quality. Further, it should involve key aspects of what information to include, planning procedures, and potential release dates to increase awareness and facilitate resources. One of the studied companies within Volvo Group included all names of the involved stakeholders in the DCN body text in KOLA. Before releasing a DCN, the design engineer needed to establish the change with all stakeholders involved. Implementing a similar system at Volvo Penta could enhance information sharing in the preparatory phase, thus ensuring that all departments are aware of, and have approved the upcoming change.

5.2.3 Standardized information in the Product Lifecycle Management system

Empirical findings indicated that the need to clarify or add additional information in KOLA is common in several steps of the DCN process. Hence, it is unlikely for DCNs to be direct runners in the process. The information captured in a DCN serves several purposes for different departments and the information must be shared efficiently. According to Baan (2013), data does not only need to be available and accessible to people working in the process but the information also needs to be relevant and interpretive. Based on empirical findings, that is not always the case in the DCN process. Some respondents stated that they only needed specific data on each DCN to perform their activities. This indicates that the information provided is not always relevant to the receiver. However, it would be highly insufficient to send customized DCNs to each department and it would complicate the traceability. Hence, it is not considered an option for Volvo Penta. Instead, the focus should be to optimize the information in KOLA based on input from each department. Further, all employees must be able to understand the DCN information in KOLA. Empirical findings indicate that there are cases where the correct DCN information has been provided but the receiver was not able to interpret the data. This highlights the importance of system education.

Further, findings indicate that previous experience is an important factor in the DCN quality. For instance, respondents at PD stated that they sometimes include information because they "know" what the other departments need, regardless of the DCN templates. For new employees, it could therefore be challenging to know what information is necessary or not. Even respondents from the review group stated that it is difficult to determine whether the DCN information is sufficient. The DCN is supposed to describe the change and includes as many details as possible, without being superfluous. At the same time, it should be factual and easy to assimilate. Finding the balance between these two aspects can challenging. Therefore, it can be argued that optimization of the DCN information must be cross-functional where each department states what specific information they need, and why it is essential for the different activities in the process. If all departments agree on a standardized KOLA template it would mitigate the risk of missing information. Further, if all necessary information is included in the DCN description, it would reduce the need to clarify information later in the process. At the same time, it is important to provide system training in KOLA to ensure that all stakeholders will be able to interpret the information from PD.

5.2.4 Process visualization and role clarification

According to Hartmann et al. (2018), information flows are considered complex and challenging to map. The reason for complexity builds upon the degree of digitalization and the range of more extensive product variants. During the interviews, respondents confirmed that the investigated DCN process is complex and hard to grasp. Likewise, respondents implied that it is challenging to interpret and visualize process steps and activities. Therefore, it can be argued that there is a need for a more adapted and user-friendly process visualization. When empirical findings were compared to current documentation, it was discovered that responsible roles were not included and certain activities were missing. For instance, the process step of setting sourcing in IPA was not included in the current process map. The detailed VSM presented in Figure 4.2 gives a more comprehensive description of how different activities and stakeholders are connected at GSC. Furthermore, the detailed VSM lacks data on lead time for different activities in the process since that data was not found during the data collection. Therefore, it can be argued that the detailed VSM is incomplete according to the classic description of VSM presented by Rother et al. (2004); Pascal (2015). However, it provides value in form of a current state analysis of the DCN process at GSC where waste has been identified. Moreover, respondents claimed that a lack of overall visualization of the process made it difficult to know what person to contact when looking for specific information. Including responsible roles and stakeholders in a future process map could help mitigate this issue. Literature on VSM 4.0, where classic VSM has been adapted to digital flows is a good way to map the value and non-value of information. The first three, out of six steps presented by Meudt et al. (2017) was followed in this case study when adapting the detailed VSM. The purpose was to show the complexity of visualizing digital information flows, aligned with Hartmann et al. (2018) theory on information management. The remaining steps in Meudt et al. (2017) method for VSM 4.0 focus on calculating data usage and identifying potential future storage systems. These steps were not applicable for this case study since no quantitative data was collected. However, the conducted VSM can be used as a foundation for future improvement projects at Volvo Penta.

According to Watts (2011), it is of essential value that different functions in the change processes know their roles and responsibilities. In terms of ownership, all respondents stated that they felt responsible for their work and activities in the process. At the same time, empirical findings implied that there was a lack of clarity regarding role descriptions in general, and how different stakeholders' responsibility connects to other departments. Moreover, empirical data indicated that most roles in the DCN process are broad and include several responsibilities. This could be a contributing factor to why areas of responsibility in the process are experienced as unclear. Although it would not eliminate the problem, having clear role descriptions for each function involved in the process would make it easier to know whom to contact and could therefore reduce unnecessary communication.

5.3 Performance Measurements

During the interviews, respondents stressed the importance of reducing lead time and improving resource utilization in the DCN process. For some activities, such as the review process, data indicated that the current lead time had increased from 2 weeks to 3-4 weeks. However, the empirical data showed that lead time is not currently measured in all process steps and respondents found it challenging to estimate the time and resources needed to perform each activity. In terms of resource utilization, it is also difficult to estimate the impact of an extra workforce. For instance, how many more mistakes would be discovered in the review process? Implying that there is an offset in terms of impact and cost. Further, according to Lindberg et al. (2015), performance measurements help organizations to identify poor performance and potential improvement areas. In the current situation, it is difficult to define and visualize the actual problem, since the available data is incoherent. It can therefore be argued that using basic measurements is the first step in improving lead-time and resource utilization in the process.

Measuring the performance of the DCN process can be challenging and several aspects need to be considered before implementing KPIs. Literature in the area suggests many KPIs that can be used to measure performance in similar processes. Several of these measurements are not currently used at Volvo Penta, thus creating a potential opportunity that the company can benefit from. However, each KPI needs to be evaluated to determine if it applies to the DCN process or not. A summary of KPIs presented by theory, KPIs used at Volvo Penta, and suggestions of KPIs to implement is presented in Table 5.1. Further, the term KPIs is often confused with PIs, or measurements in general. Based on the measurement theory presented by Parmenter (2015), one can argue that measurements suitable for the DCN process should not be classified as KPIs since the metric is not crucial for the overall business performance at Volvo Penta. Another important aspect to consider when choosing measurements for the DCN process is the different levels of PIs. According to Kattner et al. (2016), there are four levels presented in Figure 2.2 which can all apply to the process at Volvo Penta. The different levels will be considered for each suggested KPI and further discussed below.

Table 5.1: Summary of Key Performance Measurements presented in the theory chapter and findings at Volvo Penta

Key Performance Indicator	Theory	Volvo Penta	Suggested
Experienced DCN quality		x	
First time through / Direct runners	x	x	
Lead time per process step	x	x	x
Total throughput time	x		x
Open changes per process step	x		x
Open changes in total	x		x
Punctuality	x		x
Documents impacted by the change	x		
Persons involved in the process	x		
Data availability	x		
Data usage	x		
Digitalisation rate	x		

The first measurement *Experienced DCN quality* was an internal measurement previously used at Volvo Penta's manufacturing sites to evaluate the implementation of a design change. Empirical findings show that the respondents had different opinions regarding this measurement and some argued that the assessment was subjective. Measuring quality is not an easy task in general, and measuring experienced implementation success might be even harder. Further, this type of measurement has not been suggested by any of the studied literature in the area. It can therefore be argued that this measure does not add any value to the process and could be an example of a KPI that has lost its value over time.

One recurring KPI in ECM theory is *First Time Through* or *Direct runners*. It measures the number of changes that pass through the process without iteration or downstream adjustments (Gijo et al., 2014; Zhu et al., 2018; Lundqvist and Månsson, 2013). This measurement is also common in VSM theory to reduce waste in the process (Sharma, nd; Ottinger, 2021). According to findings from the case study, there have been previous attempts to use such measurement in the DCN process, with the purpose to measure how often mistakes were made. However, there was no efficient way to distinguish rework due to changed conditions in the projects from rework due to mistakes in the process. Based on the interviews, cross-functional communication and clarification of information seem to be standard practices in the current DCN process. This makes the measuring even more complicated since there is no clear definition of rework when it comes to clarifying information. Even though this KPI is recommended by several researchers within the ECM area, it is not considered to be a good fit for Volvo Penta in the current situation. The system support needed to define different types of rework and clarifications is not sufficient enough and the value of such measures can therefore be questioned.

Lead time and *Total throughput time* are two of the most common measurements used in lean management and according to Kattner and Lindemann (2017) it is highly applicable in the area of ECM. As previously discussed, lead time is only measured for certain steps of the DCN process at Volvo Penta and the total throughput time for a DCN is estimated based on project size. The detailed VSM, see Figure 4.2, clearly shows the gap in lead time for different process steps, making it impossible to calculate an actual throughput time. Another important aspect that needs to be considered is the trade-off between lead time and quality. Empirical findings indicate, that DCNs with solid preparatory work often turn out to have a higher quality and require less rework. It can be argued that more time spent on preparatory work might reduce the number of DCNs since the need for additional correcting DCNs would decrease. In this case, an increased lead time might result in less rework, which in turn, would be positive for the process in general. However, measuring lead time has several other benefits, such as detecting bottlenecks and identifying waste in the process. Studies of the ECM process confirm that lead time is a KPI used by several manufacturing companies to measure the performance of the process (Lundqvist and Månsson, 2013; Huang et al., 2003). Connected to the levels of performance indicators presented by Kattner and Lindemann (2017), shown in Figure 2.2, lead time should be measured on a detailed level for each activity in the process. This implies that lead time should be measured for different types of DCNs within each activity. At Volvo Penta, it could be equivalent to measuring lead time for different types of DCNs separately. For example, mapping new parts and existing parts as two different DCN categories. Based on these arguments, introducing lead time as a measurement would be highly valuable for Volvo Penta. Updating the count-down calendar with correct lead times for different types of DCNs would ease project planning, balance the workload, and reduce the number of urgent DCNs. At this point, however, lead time should not be used as a KPI until enough data has been gathered to set reasonable target values for the process.

Open changes per process step and Open changes in total are two measurements used to assess the volume of ECs (Huang et al., 2003; Lundqvist and Månsson, 2013). These measurements could be used on different performance levels but would be most suitable on a general level, including all types of projects. By measuring the total number of open changes, it would be possible to plan the required level of resources needed to manage the current volume of DCNs. The same goes for open changes per process step, where it would be possible to plan resources needed in each department. Measuring DCNs per process step would also help employees predict their workload. For example, if people at GSC were able to see the number of opened DCNs in the review process, it would be possible to estimate the workload for the upcoming month. In a future state, these measurements could be used as KPIs if the organization decides on a maximum number of DCN that could be handled per process step. This would help to control the workload for each function and could relieve stress for the people working in the process. According to the empirical findings, it would ease the workload for some respondents if they knew how many DCNs were to be released in the upcoming month. One respondent, in particular, stated that there should be a limit on DCN releases per week. By measuring open changes per process step it would be possible to fulfill these requests.

Punctuality is another KPI mentioned in ECM literature and previous case studies(Lundqvist and Månsson, 2013; Kattner et al., 2019). The purpose is to measure if a change notice is released on time according to the project plan. During the interviews, this measurement was also suggested by respondents at GSC as a good fit for the DCN process. The main benefit of using punctuality as a measurement would be to prevent the urgency that occurs when a DCN is released later than planned. For such measures to be sufficient, they should be applied on a specific level according to Kattner et al. (2016) framework, concerning different DCN categories. Measuring punctuality of DCNs was previously tested at one other company within Volvo Group, Company B. According to respondents, it was not a successful implementation since the planned introduction date could be adjustable in KOLA, resulting in misleading output. Hence, this measurement did not add any value to the process at Company B at the time. Based on this information, it is important to ensure that the planned implementation date is fixed, or that the system enables backtracking of the change history.

Measuring the number of documents impacted by the change, and the number of people involved in the process are two measurements presented by Riviere et al. (2003), used to evaluate the performance of ECM processes. These measurements are valuable if different types of change requests have a different impact on the organization. However, this is not the case at Volvo Penta, as all types of DCNs involve several functions across the organization. The output from such metric would therefore be similar for all types of DCNs. Hence, these metrics are not considered to be valuable for the DCN process at Volvo Penta. The last three KPIs presented in Table 5.1 are measurements suggested by Meudt et al. (2017) to visualize the utilization degree of information. Using these measurements and calculating the utilization rate is considered to be an important step in VSM 4.0. Empirical findings imply that the data needed to perform such calculation is not currently available at Volvo Penta. Further, these KPIs would not indicate the overall efficiency of the DCN-process and other measurements are considered to be more valuable for the process. However, these measurements could be useful if the company decides to evaluate information utilization as a further step of the information management strategy.

6
Conclusion and Implications

This chapter presents answers to the research questions of this master's thesis, including non-value-adding activities, improvements, and recommended measurements for the DCN process. Further, implications of this study and suggestions for further research are presented followed by specific recommendations to Volvo Penta.

6.1 Answers to the research questions

The purpose of this thesis was to investigate how manufacturing companies manage product- and sales structure changes in a structured and quality-assured way. The aim was to identify value-adding activities and suggest improvement areas to increase the efficiency of the process. Based on the qualitative analysis, it can be concluded that several types of waste appear in the studied DCN process and the thesis presents different improvement areas to mitigate waste and increase efficiency. Further, the study aimed to investigate possible KPIs to measure the value of information which has resulted in recommendations of specific measurements for the studied process.

6.1.1 What data and main activities are not value-adding in the DCN process of the case company?

Non-value-adding activities in the DCN process can be seen as different types of waste with a negative effect on the process efficiency. This thesis outline eight different wastes and through conducted VSMs, six out of eight wastes were identified in the DCN process. This thesis concludes that a single type of waste may directly or indirectly affect or cause other waste parameters. Further, this study supports that classic VSM can be adapted and used on digital information flows to identify non-value-adding activities. Irrelevant or unclear information exchange between different stakeholders in the process creates waste in form of *Overproduction* and *Unnecessary motion*. It can be argued that unnecessary communication appears as a consequence of these. Further, this study implies that the use of multiple IT systems without integration may increase waste in sense of *Transporting*, *Extra processing*, and *Unnecessary inventory*. It results in unnecessary manual data entry due to a lack of system integration. Likewise, it can be concluded that the waste of *Waiting* appears as a bottleneck considering when information is stored in backlogs as an effect of sequential work. As a consequence, it affects the total throughput time of the DCN process. The last two wastes *Defects*- and *Losing people's potential* was not directly identified in the process but appear as side effects of the other wastes.

6.1.2 How can an organization improve the efficiency of a DCN process?

There are several ways to improve the investigated DCN process, both by reducing waste and increasing knowledge. This study outline four improvement areas for the process in general to increase the efficiency of a DCN process. The findings of this study suggest that *System integration and automation* would reduce the need for manual data entry and can therefore decrease the risk of human error. Further, integrated systems would make the data transfer more efficient and reduce lead time for process steps that requires a lot of manual input. The study also supports that *Collaboration and knowledge sharing* can improve and support the DCN process by avoiding negative aspects of silo-inspired work. By adopting a joint learning platform to share knowledge through brainstorming sessions and educational workshops, it would be possible to secure knowledge sharing in the DCN process. Moreover, it could increase the overall understanding of the process and encourage future improvements. Expanded collaboration secures knowledge sharing in the DCN process and increases the affected employees' ability to understand and contribute to future improvement of the DCN process. Likewise, the study concludes that knowledge sharing through joint learning decreases the risks of knowledge gaps within the organization. Another important aspect to increase cross-functional collaboration is preparatory meetings, where all functions can discuss and prepare for upcoming changes. Further, this thesis identifies *Standardizing KOLA templates* as an improvement to ensure that all necessary information is included in the DCN. This would reduce the need for rework and additional clarification, thus avoiding unnecessary communication in the process. Lastly, this study concludes that an update of current process documentation and role descriptions would improve *Process Visualization and Role clarification*. It would increase the holistic process understanding as employees would, to a higher degree, know whom to contact when searching for certain DCN information.

6.1.3 How can an organization use key performance indicators to measure the efficiency of a DCN process?

By using carefully selected measurements, such as KPIs, an organization can measure the efficiency of a process. This study implies that not all measurements recommended by previous ECM research are applicable for the investigated DCN process, confirming that measurements need to be evaluated for each organization. Further, organizations need to consider what could be measured with available resources and what value it would add to the process. Further, the purpose of the measurement needs to be communicated throughout the organization to ensure that all employees understand the objective.

This thesis outline three categories of measurements that are considered to be beneficial for the DCN process at Volvo Penta. Further, these measurements should not be introduced as KPIs, but rather as a way to collect necessary data to understand the current state of the process. The first measurement, *lead time*, should be measured in each process step for different categories of DCNs. Based on the gathered data it would be possible to summarize the total throughput time. This data can be used to update the countdown calendar and result in a more accurate time frame. The second measurement is *volume of open DCNs*, which quantifies the volume of active DCNs in different process steps, and for the process in total. This measurement would facilitate resource planning and support a balanced workload. The third measurement recommended for the DCN process is *punctuality*, which evaluates if a DCN has been released according to plan. This measurement can be used as an indicator for urgent DCNs and thereby focus attention on resource utilization.

6.2 Overarching Theoretical and Practical Implications

All manufacturing companies working with engineering changes have some kind of process to handle product design and structural changes. The degree of complexity may vary compared to the studied DCN process, but in one way or another, change information needs to be distributed and managed throughout organizations. The findings of this study provide insights into the area of ECM by identifying digital waste, improvement areas, and possible measurements in the process. Moreover, the study confirms previous research on necessary activities presented in previous ECM research, and some of the suggested informational waste in such a process. Further, the outline of the detailed VSM created for this thesis could be used as a foundation when evaluating similar information flows and processes. Previous research suggests several KPIs used to measure the efficiency of information flows and ECM processes. Although many KPIs have been used by different organizations, each measurement needs to be evaluated for each unique situation. KPIs that are crucial for one process might not add any value to another. Therefore, the measurements recommended for Volvo Penta do not necessarily apply to other manufacturing companies.

6.3 Recommendations to Volvo Penta

As a concluding part of this case study, specific recommendations to Volvo Penta are presented as an addition to previous conclusions. These recommendations are directed toward the department of GSC based on empirical findings and qualitative analysis.

As previously mentioned, standardized information in KOLA would improve work efficiency in several parts of the process. Specifically, at GSC, this includes clarification of data that is transferred from KOLA when items are set up in IPA. The next step would be for employees at GSC to specify what DCN information is required and request an update of existing KOLA templates. Further, it would be beneficial to integrate KOLA and IPA to reduce manual data entry when items are set up in E1. Another recommendation is to automate the function of 'Mail 2' to reduce additional communication and minimize the risk of losing important information in personal inboxes. Based on the interviews, this procedure was considered to be time-consuming and insufficient by respondents who sent and received the information. Therefore it is considered to be value-adding to the process in general if Mail 2 could be removed without compromising the outcome. The details of a system adaptation need to be further investigated but the status of a DCN case in IPA should be able to trigger automatic notifications. Instead of emailing information on each IPA case, all stakeholders would be able to see when a new item has been set up in the system. An expansion of IPA could also enable the procedure of controlling DCN master data to be managed directly in the system, instead of manually exporting data to excel. An alternative, short-term solution, to reduce unnecessary communication could be to expand the use of existing follow-up lists. By inviting other stakeholders to engage with existing information, the collection of master data could be performed without sending information via email.

Based on empirical findings, the way to prioritize DCNs vary throughout the process. In the initial phases, creation, review, and release, DCNs are handled based on prioritization in KOLA. However, at GSC DSNs are managed in a continuous order and further prioritization is based on SOO. Hence, the collection of master data is conducted without regard to the prioritization in KOLA. It is therefore highly important that SOO is clearly communicated and that the date corresponds to the project plan. According to respondents, SOO is sometimes included in KOLA if the data is available when the DCN is created. Otherwise, it is up to the Project Manager to set SOO later in the process and provide GSC with an updated date. Since several stakeholders in the process prioritize their work based on SOO it is important to provide information early in the process. Further, findings indicated that relations between SOO, SOP, and SOD caused unclarity and confusion in the process, as people from different functions often refer to different dates. A standardized way to update and communicate SOO/SOP/SOD to all stakeholders would ensure that the right DCNs are prioritized and reduce the risk of urgent DCNs.

Furthermore, the results from this study imply that the workload connected to the DCN process has increased over the last years and several respondents stated that they often need to work extra hours to manage the workload. When employees are forced to manage a large volume of DCNs in a limited time, the risk of manual errors increases, and the quality could be affected. Therefore, it is recommended that management at GSC evaluates the resource utilization in the DCN process to ensure that all employees have the right conditions to perform their work. For example, one way to balance the workload could be to limit the number of DCNs released per week. Another suggestion is to demand a DCN release forecast from PD each week, which gives GSC the ability to plan for upcoming weeks.

6.4 Further Research

To validate the findings from the DCN process at Volvo Penta, it would be relevant to conduct a multiple case study. By comparing processes at similar companies it would be possible to identify common wastes in the ECM process and decide on a best practice. Future research could also include a longitudinal study at Volvo Penta to assess the long-term effects of using measurements and KPIs in the DCN process. Mapping lead time for different types of DCNs over a longer period would improve the accuracy of the total throughput time and enhance resource utilization. Such a study could also quantify the non-value adding time in different activities and identify bottlenecks in the process. The scope of this study was limited to physical design changes affecting the sales structure. If the area of ECM is to be moved forward, a better understanding of software changes needs to be developed. It would therefore be of interest to investigate how ECM theory could be adapted to software changes, to produce findings that account for digital products and services.

Bibliography

Ackoff, R. L. (1989). From data to wisdom. *Journal of applied systems analysis*, 16(1):3–9.

Astalin, P. (2013). Qualitative research designs: a conceptual framework. *International Journal of Social Science and Interdisciplinary Research*, 2(1):118–124.

Baan, P., editor (2013). *Enterprise Information Management*, volume 1. Springer, New York.

Bell, E., Bryman, A., and Harley, B. (2019). *Business Research Methods. 5th Edition.* Oxford University Press., Oxford.

Blomkvist, P. and Hallin, A. (2015). *Method for Engineering Students: Method For Engineering Students: Degree Projects Using the 4-phase Model. 1th edition.* Studentlitteratur, Lund.

Boaden, R. and Lockett, G. (1991). Information technology, information systems and information management: definition and development. *European Journal of Information Systems*, 1(1):23–32.

Braun, V. and Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2):77–101.

Bremer, M. and Cohnitz, D. (2004). *Information and Information Flow : An Introduction*, volume 1. De Gruyter, Inc., Berlin/Boston, GERMANY.

Condens (n.d). User interview analysis approach. `https://condens.io/user-interview-analysis/#approach`.

Diprima, M. (1982). Engineering change control and implementation considerations. *Production and Inventory Management*, 23(1):81–87.

Earley, T. (n.d). Vsm value stream mapping. `https://leanmanufacturingtools.org/549/vsm-value-stream-mapping/`.

Editorial, I. (2021). What is information management? definition and benefits. *Indeed*.

Eisenhardt, K. and Graebner, M. (2007). Theory building from cases: Opportunities ans challanges. *Academy of Management Journal*, 50(1):25–32.

Flyvbjerg, B. (2006). Five misunderstandings about case-study research. *Qualitative Inquiry*, 12(2):219–245.

Gijo, E.V.and Antony, J., Kumar, M., McAdam, R., and Hernandez, J. (2014). An application of six sigma methodology for improving the first pass yield of a grinding process. *Journal of Manufacturing Technology Management*, 25(1):125–135.

Gopinath, S. and Freiheit, T. (2012). A waste relationship model and center point tracking metric for lean manufacturing systems. *IIE Transactions*, 44(2):136 – 154.

Hartmann, L., Meudt, T., Seifermann, S., and Metternich, J. (2018). Value stream method 4.0: holistic method to analyse and design value streams in the digital age. *Procedia CIRP*, 78:249–254. 6th CIRP Global Web Conference – Envisaging the future manufacturing, design, technologies and systems in innovation era (CIRPe 2018).

Hicks, B. (2007). Lean information management: Understanding and eliminating waste. *International Journal of Information Management*, 27(4):233–249.

Huang, G., Yee, W., and Mak, K. (2003). Current practice of engineering change management in hong kong manufacturing industries. *Journal of Materials Processing Technology*, 139(1):481–487. IMCC2000 Vol. 2 S.I.

Huet, G., Pellerin, R., Fortin, C., Mcsorley, G., and Toche, B. (2010). Information structures and processes to support data exchange between product development and production planning & execution systems. *Journal of Operations and Logistics*.

Jaratt, T., Caldwell, N., and Clarkson, P. (2011). Engineering change: An overview and perspective on the literature. *Research in Engineering Design*, 22:103–124.

Jokinen, L., Vainio, V., and Pulkkinen, A. (2017). Engineering change management data analysis from the perspective of information quality. *Procedia Manufacturing*, 11:1626–1633. 27th International Conference on Flexible Automation and Intelligent Manufacturing, FAIM2017, 27-30 June 2017, Modena, Italy.

Kattner, N., Hu, S., and Lindemann, U. (2019). Defining effort indicators to retrospectively assess engineering change information. In *2019 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*, pages 154–158.

Kattner, N. and Lindemann, U. (2017). Performance metrics in engineering change management: Towards a methodology to investigate the efficiency of handling engineering changes. *Portland International Conference on Management of Engineering and Technology (PICMET)*, pages 1–8.

Kattner, N., Wang, T., and Lindemann, U. (2016). Performance metrics in engineering change management - key performance indicators and engineering change performance levels. *International Conference on Industrial Engineering and Engineering Management (IEEM)*, pages 1180–1184.

King, W. R. (2009). *Knowledge Management and Organizational Learning*. Springer US, Boston, MA.

Kleindorfer, P. R., Singhal, K., and Van Wassenhove, L. N. (2005). Sustainable operations management. *Production & Operations Management*, 14(4):482 – 492.

Kolinski, A. and Jaskolska, E. (2018). Analysis of the information flow efficiency in the intermodal supply chain - research results. *Proceedings of International Scientific Conference Business Logistics in Modern Management*, pages 135 – 156.

Lincoln, Y. S. and Guba, E. G. (1985). *Naturalistic inquiry*. sage.

Lindberg, C.-F., Tan, S., Yan, J., and Starfelt, F. (2015). Key performance indicators improve industrial performance. *Energy Procedia*, 75:1785–1790. Clean, Efficient and Affordable Energy for a Sustainable Future: The 7th International Conference on Applied Energy (ICAE2015).

Lundqvist, M. and Månsson, A. (2013). Improvement of an engineering change process a case study at ascom wireless solutions. Master's thesis, Chalmers University of Technology, Gothenburg.

Lupanava, S. (2017). Defeating high employee turnover with knowledge management tools. `https://www.kminstitute.org/blog/defeating-high-employee-turnover-knowledge-management-tools`.

Madden, A. (2000). A definition of information. *Aslib Proceedings*, 52(9):343–349.

Madenas, N., Tiwari, A., Turner, C. J., and Woodward, J. (2014). Information flow in supply chain management: A review across the product lifecycle. *CIRP Journal of Manufacturing Science and Technology*, 7(4):335–346.

McCreadie, M. and Rice, R. E. (1999). Trends in analyzing access to information. part i: cross-disciplinary conceptualizations of access. *Information Processing & Management*, 35(1):45–76.

Meudt, T., Metternich, J., and Abele, E. (2017). Value stream mapping 4.0: Holistic examination of value stream and information logistics in production. *CIRP Annals - Manufacturing Technology*, 66.

Morin, M., Jacquet, P., Vaesen, K., and Acerbi, A. (2021). Social information use and social information waste. *Philosophical transactions of the Royal Society of London. Series B, Biological sciences*, 1824(376):103–124.

Okes, D. (2013). *Performance Metrics : The Levers for Process Management*. ASQ Quality Press, Milwaukee, UNITED STATES.

Ottinger, T. (2021). First time through. `https://www.industriallogic.com/blog/first-time-through/`.

Parmenter, D. (2015). *Key Performance Indicators : Developing, Implementing, and Using Winning KPIs*. John Wiley & Sons, Somerset, UNITED STATES.

Pascal, D. (2015). *Lean production simplified : a plain-language guide to the world's most powerful production system / Pascal Dennis ; foreword by John Shook*. CRC Press, Boca Raton, Florida ;, third edition. edition.

Prasad, B. (1996). Toward definitions of a concurrent product design, development, and delivery (pd 3) system. *Concurrent Engineering*, 4(2):102–109.

Riviere, A., DaCunha, C., and Tollenaere, M. (2003). Performance in engineering changes management. *Recent Advances in Integrated Design and Manufacturing in Mechanical Engineering*, 1:369–379.

Roh, P., Kunz, A., and Wegener, K. (2019). Information stream mapping: Mapping, analysing and improving the efficiency of information streams in manufacturing value streams. *CIRP Journal of Manufacturing Science and Technology*, 25:1–13.

Rother, M., Shook, M., and Helling, J. (2004). *Lära Sig Se: Att Kartlägga Och Förbättra Värdeflöden För Att Skapa Mervärden Och Eliminera Slöseri: En Handbok För praktisk Tillämpning Av Metoder Och Verktyg För Lean Produktion*. Lean Enterprise Institute Sweden, Gothenburg.

Saunders, M., Lewis, P., and Thornhill, A. (2016). *Research Methods for Business Students*, volume 7. Pearson Education Limited.

Scott, J. (1990). A matter of record: Documentary. *Sources in Social Research*.

Shahin, M., Ali Babar, M., and Zhu, L. (2017). Continuous integration, delivery and deployment: A systematic review on approaches, tools, challenges and practices. *IEEE Access*, 5:3909–3943.

Sharma, S. (n.d). Lean services: Doing transactions right the first time.

Slack, N. and Lewis, M., editors (2019). *Operations Strategy*, volume 6. Pearson Educated Limited, Harlow.

Squires, A. (2009). Methodological challenges in cross-language qualitative research: A research review. *International Journal of Nursing Studies*, 42(2):277–287.

StatisticSolution (2020). What is credibility in qualitative research and how do we establish it? `https://www.statisticssolutions.com/what-is-credibility-in-qualitative-research-and-how-do-we-establish-it/`.

Stekolschik, A. (2016). Engineering change management method framework in mechanical engineering. *IOP Conference Series: Materials Science and Engineering*, 157:012008.

Verrier, B., Rose, B., and Caillaud, E. (2016). Lean and green strategy: the lean and green house and maturity deployment model. *Journal of Cleaner Production*, 116:150–156.

Watts, F. B. (2011). *Engineering documentation control handbook: configuration management and product lifecycle management*. William Andrew.

Wiley, J. and Sons (2009). *Information Storage and Management : Storing, Managing, and Protecting Digital Information*, volume 1. EMC Education Services and John Wiley & Sons Incorporated, Hoboken, UNITED STATES.

Wu, W.-H., Fang, L.-C., Wang, W.-Y., Yu, M.-C., and Kao, H.-Y. (2014). An advanced cmii-based engineering change management framework: The integration of plm and erp perspectives. *International Journal of Production Research*, 52.

Zhu, L., Johnsson, C., Varisco, M., and Schiraldi, M. M. (2018). Key performance indicators for manufacturing operations management – gap analysis between process industrial needs and iso 22400 standard. *Procedia Manufacturing*, 25:82–88. Proceedings of the 8th Swedish Production Symposium (SPS 2018).

A

Interview List

Interviews conducted during the case study with respondents from Volvo Penta and other companies within Volvo Group

Volvo Penta			
No.	**Role**	**Department**	**Date**
1	DCN coordinator	GSC	2022-02-25
2	DCN coordinator	GSC	2022-03-07
3	SCPM	GSC	2022-03-07
4	SCPM	GSC	2022-03-08
5	Price coordinator	Business unit Marine	2022-03-08
6	Product prep documentation engineer	Vara Operations	2022-03-09
7	Sales structure specialist	Business unit Marine	2022-03-09
8	BDP and Custom case manager	Process development	2022-03-10
9	Project Manager GOQ	Industrial Development	2022-03-14
10	Chief Project Manager	Projects and execution	2022-03-14
11	Director	Parts & Services	2022-03-15
11	Product planner	Parts & Services	2022-03-15
11	Product planner	Parts & Services	2022-03-15
12	Project Manager Purchasing	Purchasing	2022-03-15
13	DCN specialist	Product Development	2022-03-16
14	Supply Chain Coordinator	GSC	2022-03-16
15	Project Manager Purchasing	Purchasing	2022-03-17
16	Product Development Engineer	Product Development	2022-03-21
17	Project Manager Design	Product Development	2022-03-23
18	PDM specialist	Product Development	2022-03-24
19	Product Manager D17	Product Development	2022-03-31

Volvo Group			
No.	**Role**	**Department**	**Date**
20	Senior product document specialist	Platform Development	2022-03-28
21	Manager product documentation	Powertrain engineering	2022-03-28
21	KOLA & Product structure specialist	Powertrain engineering	2022-03-28

B

Interview Guide

Profile of the Sample

- What role do you possess at Volvo Penta?
  - What business area/department?
- What activities do you manage in the DCN-process?
  - What part of the process?
- If you estimate, what percentage of your role involves working with DCNs?
- Years of experience in DCN process?

Identify activity in DCN-process

- Can you describe the activities that you perform in the DCN process?
  - What data/information do you add to the DCN?
- In your experience, do you feel that you have all prerequisites to perform your work?
  - Do you have access to all data to manage your tasks?
  - How are you notified that you received a DCN that you shall work on?
  - Do you have system support to manage your task?
- How do you prioritize different DCNs?
  - If an urgent DCN occurs, how do you handle it?
- Can you describe how you work with other people in the DCN-process?
  - What information do you receive/share with these people and why?
  - How does your work in the DCN-process depend on these people?
  - How do you communicate with these people (E-mail, Teams, face-to-face, ERP system etc.)?
  - Have you ever needed to redo a DCN or contact other people to clarify the information that you received?
- How would you estimate the time required to perform your work tasks in the DCN-process in total per week?
  - Can you estimate the time required for each article in a DCN?
  - How do you manage the DCN workload over the week (daily/batch)?
  - Do you consider it a manageable workload in order to handle all DCN with high quality?
- Can you describe the DCN-process as a whole?
  - In your experience, do you have a good holistic understanding of the process?
  - Who is responsible for your part of the DCN process (ownership)?

Identify problem areas

- Could you describe a situation when the DCN-process was challenging?
  - Why was this challenging?
  - How did you solve it?
- Have you experienced any blockers considering your work in the DCN process?
  - How would you suggest removing these blockers?
- Based on your experience, what parts of DCN process work well?
  - Why does it work better than other parts of the process?
  - Would you argue that these differences appear based on years of experience in the DCN process?
- Are there any parts of the DCN process that you consider critical in order to perform your work -Have you experienced issues with?
  - Follow-up lists?
  - Communication with the DCN-coordinator?
  - Communication with CPMs?
  - Functions in IPA/E1?
  - Prioritization/Classification?
  - Working in Silos, no holistic perspective?

Identify improvement areas

- In your point of view, what would a best practice DCN process look like?
  - What improvement areas do you consider important for the process as a whole?
  - What improvement areas do you consider important to support your role in a better way?
- Based on your experience, what impact would KPI's have on the DCN process?
  - How would the use of KPI's in the DCN process affect your work?
  - What type of KPI's would ease your work?
  - Do you consider KPI's as positive or negative?

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