A Study of an Order to Delivery Value Flow

Master's thesis in Industrial Engineering and Management, Optimization and Logistics

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Abstract

Engine manufactures are continually challenged with new and stricter emission regulations, which affect the total cost of the product. At Volvo Penta, where the study is conducted, increased product cost as one of the consequences from the regulations were discovered. Two engine types were assessed in this study whose production is outsourced to Volvo Powertrain, another part of the Volvo Group. To increase the understanding of the business and to improve the performance of the company, the methodology of Value Stream Mapping was used to highlight waste generating activities and the areas of improvement. The focus was therefore shifted from product cost to process cost. To create an efficient flow, the cooperation between Volvo Penta and Volvo Powertrain was assessed to find suggestions for a preferred future state. The scope of this study was to evaluate the nonproduction areas related to the engines, i.e. the order management, procurement of material, delivery etc.

It was detected during observations and field trips at the production facilities that there are areas of improvement regarding the communication between Volvo Penta and Volvo Powertrain, that manufactures the engines. To create an efficient flow in both administrative processes and the production, cooperation is inevitable. Optimizing the order to delivery process requires efforts to create a steady flow with minimal disturbances and waiting time. Since the order responsibilities are divided in different departments at Volvo Penta, there can arise waiting times for orders as a result from the communication methods. It was found that the administrative processes can support the production by leveling the mix in the complexity of the engines, which would result in a smoother flow and an even demand of material. To maximize value for the customer, the processes can be optimized by increasing the flow efficiency in both order administration and the production, since both parts are linked to each other. One approach to improve the order administration from the customer's point of view is to form cross functional teams, combining people with different fields of work and bringing more flexibility and standardized work into the business. Focusing on the flow brings several advantages for the company, such as higher responsiveness, shorter lead times and improved performance.

Keywords: Lean Office, Value Stream Mapping, Administrative value flow, Supply Chain Management, Performance, Order to Delivery, Logistics

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Evamarina Al-nazary, Gothenburg, June 2019

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Abbreviations

%C&A	Percent complete and accurate
ASE	Authorized Stock Engine
CONWIP	Constant Work in Process
CPO	Central Planning Office
DC	Distribution Center
DCN	Design Change Notice
E1	JD Edwards Enterprise 1
GASS	Global Assembly Steering System
KPI	Key Performance Indicator
KRI	Key Result Indicator
MACS	Material Control System
OTD	Order to Delivery
PI	Performance Indicator
PL	Volvo Production Logistics
PO	Customer Purchase Order
RI	Result Indicator
SCC	Supply Chain Coordinator
SCM	Supply Chain Management
SO	Sales Order
VGMS	Volvo Group Management System
VSM	Value Stream Map
WIP	Work in Process

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1 INTRODUCTION

The report is introduced with a section explaining the problem background in relation to the company where the study is carried out. Further, the purpose of the study is clarified, and the research questions are specified.

1.1 Background

Volvo Penta is an established engine manufacturer that is part of the Volvo Group. The engines that are produced are for marine and industrial applications, and the production facilities are located mainly in Sweden.

The competition amongst engine manufacturers is continually increasing and stricter emission regulation challenge the companies with the need to increase the complexity within the engines and the software related to them. Stage V is a regulation for nonroad engines in Europe, that takes effect 2019. The consequence of these new emission standards for engine manufacturers is that the total cost for the product will rise due to inevitable changes in the process and the engine itself, such as reduced fuel consumption, substituting of components, further development of the engine aftertreatment system etc.

These costly additions drive the companies to also compete on the price. This is where the whole process, i.e. the value chain, from customer order to delivering the finished product needs to be mapped and analyzed, to find potential improvement areas. Since the production of the products is outsourced to other Volvo facilities and all of the work is divided into different departments at Volvo Penta, Volvo Penta does not automatically have a clear view of the full process and in what way the different parts in the process interact and depend on each other.

There are currently multiple divisions at Volvo Penta working separately with different matters related to the engines, for instance purchases, product development etc. The production of the two engine families, D11 and D13 industrial, is outsources to Volvo Powertrain Vénissieux and Skövde, owned by the Volvo Group. As a successful company, each division at Penta manage and optimize their work individually, but with limited knowledge of the later phases in the chain. Therefore, it may be profitable to attempt to optimize the entire value chain.

This study is part of a project that applied the methodology of value stream mapping to present recommendations to Volvo Penta. The project consists of two master theses, whereof the other one focuses solely on the production with a Lean production perspective, and this study considers aspects outside of the production itself, i.e. the supply chain, other logistics related factors and the material and information flow. Together, the two theses form an understanding of the current situation that enables Volvo Penta to examine the whole process and improve their performance.

1.2 Purpose

Due to the globalization and the rapid technical development, Volvo Penta as an engine manufacturer needs to optimize the overall process of producing their products to be able to keep up with the competition, by getting their product out in market quickly and working effectively. To be able to optimize something, different parameters and KPIs need to be defined, and by boosting the KPIs, the company's overall performance can be increased. The performance is also affected by other factors that are not described with numbers.

The new legislation, Stage V, has presumably caused some setbacks with regard to efficiency. The purpose of this study is to find potential improvements at Volvo Penta to increase the performance, with the help of an assessment of their value chain from order to delivery. Performance is something that needs continual improvement work which Volvo Penta will be able to do since a framework will be created, that can be used as a tool in the future to make similar assessments.

1.3 Scope

This study will attempt to find potential improvement areas, but it does not include implementing of the ideas. It will mainly analyze the processes directly related to the product and the customers. The products that will be analyzed are two nonroad (industrial) engines (D11, D13) manufactured in the Volvo Powertrain factories in Vénissieux, France (Vénissieux Engine Plant), and Skövde, Sweden (Powertrain Production). Volvo Penta and the two Powertrain factories all three belong to the Volvo Group. The focus is on the overall picture of the value chain with the information and material flow, not the core production process.

1.4 Problem Definition

Three questions have been defined and are intended to be the basis of this study in order to reach the goals of the project.

Although the different divisions at Volvo Penta have their individual goals and performance indicators, they all share the common objective of maximizing the overall performance for the whole company. The concept of performance has various definitions in different industries and in the literature. It consists of several dimensions, i.e. performance measures, that need to be defined and measured in order to enhance them.

Question 1.

How does Volvo Penta define and measure their performance in their value chain and how does it differ from the literature?

Since the new legislation, Stage V, is the issue that motivates Volvo Penta to assess their operations, therefore, it is crucial to investigate the changes that it brought to different fields in the company.

Question 2.

In what way does Stage V affect Volvo Penta's value chain and performance?

A value chain consists of a series of activities that bring the product from order to delivery (OTD). By mapping all the events, the value chain can be visualized and the value adding and non-value adding activities will be distinguished. The answer to the following question ought to cover the whole process from the beginning to the delivery to customer, to eventually suggest improvements that benefit Volvo Penta.

Question 3.

What activities affect Volvo Penta's performance of the OTD process and how can they be managed and optimized?

2 METHODOLOGY

This section describes the approach to answer the research questions that are the base of this study and that are presented in the previous chapter. The process is illustrated in Figure 1. To fulfil the purpose of the study and to gain results that give a fair picture of reality, different sources of information has been utilized. The disposition of the methodology description starts with the theoretical background, where the process of information gathering in literature and on the web, is presented. The following section contains a description of the practical methods used in the work and how the literature was utilized. During the work, the two relevant production facilities were visited, which is described in the third subchapter. Finally, the methodology chapter is rounded off with a subchapter about quality and how to ensure high credibility for the study.

2.1 Theoretical Methodology

To give an understanding of why this study is carried out and how the performance of Volvo Penta can be increased, different sources of literature has been studied. Since the work involves increasing of efficiency, Lean is a helpful topic to consider, along with other subjects, e.g. analyzing what performance actually is and how it is perceived from different parties. Through a deductive procedure, the presented theory in chapter three has set the foundation for the practical approach in this study.

Background studies about Volvo Penta and how they cooperate with other parts of the Volvo Group set the base for further research within the subject. The company's own website and the intranet for the employees' present background information and also a depiction of the processes. Volvo Group Management System (VGMS) shows a map of most of the administrative and manufacturing areas of the Volvo Group, including Volvo Penta, and is accessed by employees and thesis workers.

The theoretical framework presented in Chapter 3 is used to analyze the current state at Volvo Penta, thus, the study is based on a deductive research approach. An alternative method that could be used in research is an inductive approach, which implies developing of a new theory by collecting data. The reasons behind the choice of a deductive methodology are the character of the research questions, where increasing the performance of the company is the aim. A deductive approach involves explaining and predicting of the reality based on existing theories, and also testing them. This approach was considered to be the most suitable for this study, since Lean philosophy and existing KPIs to assess the performance were intended to be applied to gain the desired results. Moreover, the deductive methodology appears to be the common approach of supply chain and logistics researches (Golicic, et al., 2005). The theory behind Value stream mapping and principles of Lean were used to analyze and describe the value chain of Volvo Penta's processes.

2.2 Practical Methodology

The practical work had its starting point at Volvo Penta, naturally since they are the initial recipients of the customer orders. A pre-study was carried out which includes observation of the office environment and the way of working. Literature review, observations and interviews along with continual documentation of the process was set to be the baseline of this study. The interviews are the main source of information about the company, OTD process etc. and they were performed with a semi-structured interview approach. The reason behind the interview technique is that profound answers were preferred, thus, a number of predefined questions were presented together with tailored questions to the interviewed person. A semi-structured interview allows more open answers within the addressed topic and is one of several methods for qualitative studies (Justesen & Mik-Meyer, 2013).

By interpreting the interview results by means of the theoretical framework, a current state map was formed by using the methodology of value stream mapping. It is illustrated from the beginning where the customer makes an order, and where the components are ordered from a manufacturer, to the end station where the engine is placed and stored in a hub until it is collected. By mapping the whole process from start to the end, potential improvement areas are recognized.

The current state map breaks down the process into value adding and non-value adding activities and highlights improvement areas and bottlenecks. The data that was collected through interviews consists mainly of times for the activities, quantity of components and products etc. The process was inspected in order to find out how the information flows, how long it takes and the reasons behind it. For instance, what needs to be done for the process to move forward in certain steps and which divisions need to be involved. Also, it is important to identify the different divisions’ view on their performance and how it is evaluated. To have the right tools to do this, literature studies and interviews was carried out. Tracing the outline of the current state map was done through observation of the factories, the inventories and the office. The map was built up gradually by adding details and numbers connected to the activities in the value chain, while literature and interviews was used to support the approach and the outcome.

The result of the analyzing process of the current state map is a future state map, that is formed after following the Value Stream Mapping (VSM) principles. Eight questions are asked during the VSM process, to design the optimal suggestion of a future state. The theoretical framework behind VSM is presented in the theory-chapter, under Chapter 3.5.

2.3 Field Trips

This study is carried out at Volvo Penta’s facility in Gothenburg, and information and observations were available to attain throughout the work. However, as mentioned before, all the engines are manufactured at different facilities, where they each have their own order offices. The facilities in Skövde and in Vénissieux were visited to collect information through interviews and observations. The advantage of interviews at the factory is the closeness to most of the significant processes, namely the production.

Through observing, different perspectives of a phenomenon can be captured since information out of interviews not always match reality. Observation as a part of the methodology used in research can be in the form of "non-participant observation" and "participant observation". The difference between these two approaches is that "non-participant observation" involves observing as a third party, and "participant observation" means that the research-worker is employed during the study and merged into the observed group (Wisker, 2001). The direct non-participant observation approach was pursued in this study.

2.4 Quality

Through triangulation, several dimensions of the situation can be captured. The interview questions and answers overlap in most of cases, which gives a more detailed picture of the reality. For the information to be credible, observations were done both at the Volvo Penta office and the two named factories and compared to all other information that was received. The observations also complement the results from the interviews, and the interviewees' answers were documented directly. Reliability and validity are considered in connection with the interviews and information gathering, to ensure that the results are accurate enough and that the right information is gathered. Reliability in this context means that the information is interpreted similarly by different people and that the results are reproducible. To achieve high reliability, the value stream map of the OTD process should resemble the reality so that the results would be similar if done by someone else. By using triangulation as described in the previous paragraph, the map gives a more real picture of the reality. Observation of, for instance, the inventories, gives a higher reliability compared to if it was described by secondary sources.

Validity, however, represents the ability to measure the right thing in the right way. In this case, to yield the desired results, the interview questions were suited for each person according to their field. Adjusted interviews instead of common questions to all participants prevents misinformation, so that they respond according to their own expertise. Triangulation is one of the methods to increase validity. By maintaining communication with the interviewees after the interviews, feedback was received regarding the interview questions and other related topics, to build a trustworthy base of information about the current situation, and also collect examples of bottlenecks and suggestions on possible improvements. Due to the study involving a non-participant observation, a good way to portray the actual picture of the daily work is done by with the actual employees of Volvo Penta and the concerning factories.

The same procedure will be repeated considering the engine (D11) manufactured in the Vénissieux factory. The processes related to the two different engines deviate in some aspects, however, the feedback from the interviewees was used as inspiration and possible opportunities for both parties. The concluding result that will be delivered to Volvo Penta will be maps over the current state and the recommended future state, for both of the factories.

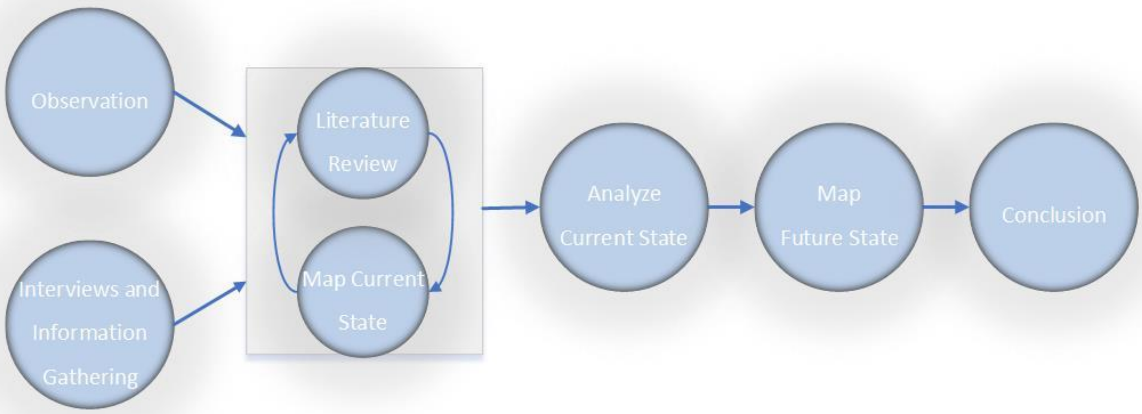

Figure 1. Flowchart of the approach of the study

3 THEORY

This chapter will describe the theoretical framework that will be applied to the choice of methods and the final analysis. The chosen topics are relevant to fulfil the purpose of this study. Supply chain management is presented in this theoretical framework since the order to delivery process is a part of a more comprehensive supply chain. Every supply chain is designed differently and is characterized by the planning and control of the organizations. The planning and control in turn effects the performance of the organization, which is assessed in this study, hence the clarification of the meaning of performance. Lean philosophy and Value Stream Mapping are also some of the topics explained in this chapter, to support the methodology used in this study and the analysis of different operations at Volvo Penta, and to present a viable recommendation of a future state. The chosen topics are intended to be the baseline of the analyze of Volvo Penta's value chain in the order to delivery process.

3.1 Supply Chain Management

The creation, selling and distribution of a product requires numerous parties and resources. *Supply chain* is the term that describes this network of people and organizations, that support the process of bringing a product to the end user. It also includes the conveying of a finished product from the factory to the customer, which is called the distribution channel. The management of this system of different elements is called supply chain management (SCM), and involves organization of the resources, communication and assets in the progress of shaping a product or service into a deliverable. The supply chain consists of three essential flows: information flow, product/material flow and financial flow, and supply chain management is about synchronizing the interaction between the flows. The coordination of the flows reaches across both internal and external boundaries of a company (Rouse, 2013).

Mentzer, DeWitt and Keebler (2001) defines supply chain management as: "...the systemic, strategic coordination of the traditional business functions within a particular company and across businesses within the supply chain, for the purposes of improving the long-term performance of the individual companies and the supply chain as a whole". Basically, it involves controlling the flow of materials, information, services and capital within an organization, as well as across the various organizations and parties in a supply chain, which is illustrated in Figure 2. (Mentzer, DeWitt & Keebler, 2001). It is one of the most essential operations among organizations when it comes to efficiency and gaining competitive advantages (Feng & Wang, 2013).

There exist various advantages that can be achieved by effective supply chain management (SCM). SCM can lead to reduced production and logistics costs through efficient collaborations between the numerous organizations involved in the supply chain that improve the flow efficiency. The reduced cost related to production and logistics can therefore create possibilities for organizations to improve their customer satisfaction as well, where flexibility, lead time and delivery precision are included, which is one of the core goals for any company (Chou, Tan & Yen, 2004).

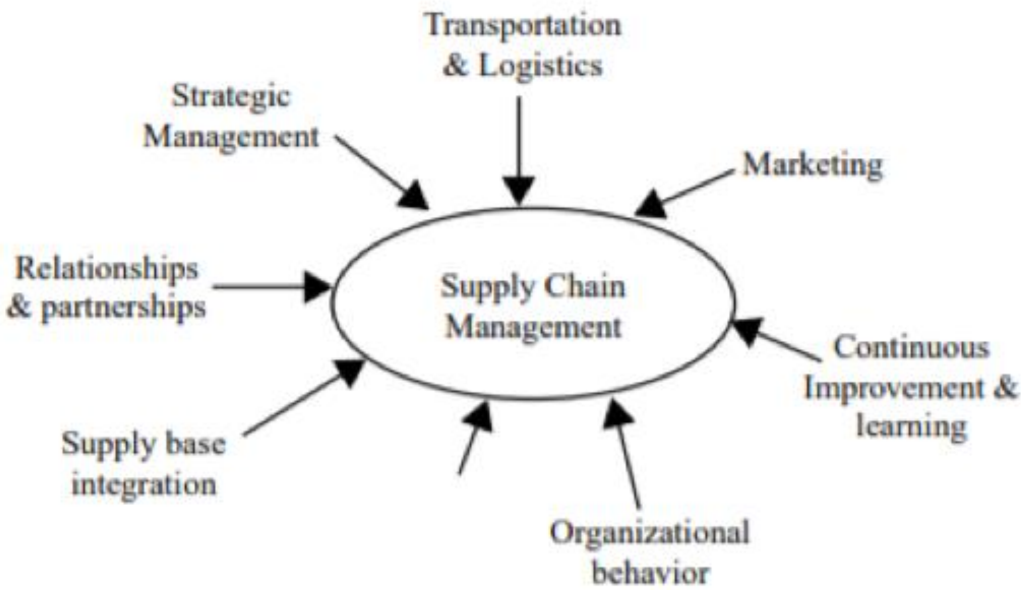

Figure 2. Illustration of the main aspects and strategies related to supply chain management (Robinson & Malhotra, 2005).

The objectives that set the base for effective supply chain management practices according to Chou, Tan & Yen (2004) are:

- Reducing inventory cost by implementing just-in-time inventory management strategies and adjusting production to demand.
- Reducing various production cost through efficient flow of materials and information within as well as across organizations.
- Improving customer satisfaction with shorter lead time from order to delivery and increasing flexibility by collaborating with other parties in the supply chain

The authors further state that planning processes are often divided into different functions in a supply chain and include the following:

1. demand planning, which regulates the quantity of products based on forecasting
2. supply planning involves ensuring sufficient levels in the safety stock
3. manufacturing scheduling, to organize the production according to resources
4. transportation planning aims to optimize the storage of inventories and the method of transport

3.1.1. Suppliers

The suppliers are essential actors in the supply chain connected to a product, and also in the different stages in the product lifecycle. They are the sources of material, determining the quality and the delivery precision of their deliveries, which also affects the pace of the production. The Order to Delivery process is highly influenced by the suppliers, since they are directly affecting the lead time for the products. The effect on the product's lifecycle can also appear during production, where quality issues may be discovered, or after the customer has received the product, causing complaints from the customers. To build trust between the suppliers and the organization, different factors need to be considered, e.g. good prices, high quality, avoid conflicts of interest etc. By working closely with the suppliers, the organization obtains different benefits like reduced costs, elaborated innovation, stronger relationships and process improvements, since the suppliers form a better understanding of the organization and their principles. Close cooperation with the suppliers can also give them the incentives to prioritize the organization in terms of efforts and delivering in time (Corrigan 2018).

The involvement of the suppliers is also beneficial seen from an environmental and innovations point of view. The constantly globalizing business world has pushed industries to develop sustainable and innovative products at a fast rate, minimizing the time between ideas to product launching. Involving the suppliers at an early stage in the product lifecycle and the product development is beneficial since it has been showed that the suppliers have a significant impact on the product quality and profitability. By integrating the suppliers in the organization's activities, their expertise and knowledge can be utilized to form sustainable, durable and innovative solutions. This results in more resources to become and remain competitive on the market, although it requires a well-planned approach to create new types of collaborations with the suppliers. Sharing the responsibility to develop products with the suppliers gives the organization more time to focus on value adding activities within their areas of expertise (Handfield, Ragatz, Petersen & Monczka, 1999).

The integration of the suppliers in the product development phase is a long-term approach which will be rewarding in the long run, if done right. Committing to collaborate with specific suppliers can restrict some of the opportunities for an organization, which makes it even more important to choose collaborations based on different criteria aligning with the organization's goals and strategies. The technical development in a company can be enhanced with the help from suppliers, enabling them to be in the technical leading edge by reducing the lead times from ideas to a finished product. To obtain these advantages, it needs to be assured that the suggested suppliers are highly competent and professional, with the incentives to contribute to an effective collaboration (Handfield, Ragatz, Petersen & Monczka, 1999).

Successful results from involving the suppliers in the product development, are seen in forms of reduced lead times in the product development area, fewer costly adjustments and engineering change notices, improved communication to avoid rework, reduced maintenance costs and less complaints from customers, which finally leads to more satisfied customers (Birou & Fawcett, 1994). Developing the interaction between all parties involved in the supply chain makes the chain more responsive to changes, flexible and enables controlling of lead times in the value chain. The performance of the company can therefore be improved and by starting close collaborations with the suppliers, the pace of the development can be boosted, and quality issues can be avoided.

3.1.2 Order to Delivery

Considering that the order to delivery (OTD) flow is directly related to the supply chain, both concepts need to be explored in order to understand the entire flow. An effective supply chain improves the OTD process. The term "order to delivery" is often used in the automotive sector, in fact in all sorts of industries, and can be viewed from different perspectives and levels of detail. Other terms, such as "order fulfillment" and "Market Flexible Customizing System" are also mentioned in connection with the same subject. It should be adapted to the market that the company is targeting and configurate the process in a way that allows them to evaluate and improve the performance of the company based on different performance metrics (Brabazon & MacCarthy, 2017).

The order to delivery process is initiated by a customer order sent to the company in question and is usually finished when the order is delivered to the end customer. While the description of the flow can have different levels of detail, one way to picture the OTD process is to divide it into seven stages: “order entry, order bank, order scheduling, order sequencing, manufacturing, distribution to distribution center (DC) and transportation from DC to dealer.” (Brabazon & MacCarthy, 2017).

Delivering the right product with the design required from the customer, at the right time, is the aim of the OTD process. It is beneficial to configurate the OTD process of the company so that it achieves relatively short delivery times for customized products, maintains the agreed timeframe for delivery and allows flexibility for order changes. Balancing different ambitions in the OTD process can be difficult since both customer service and cost minimization is vital to performance of the company. Brabazon and MacCarthy further mention a broad range of performance metrics, collected from different sources, that can be applied to the OTD process: lead time, stock level, lost sales, proportion delayed, proportion compromising, degree of compromise, etc. Many of the measures are related to customer service and require a study of the customers and the market to support the conclusions drawn from the performance measurements (Brabazon & MacCarthy, 2017).

To improve the OTD process, the understanding of the supply chain of the product is important and should be assessed to form an efficient and effective supply chain, and therefore also benefit the OTD process.

3.1.3 Supply Chain Efficiency and Effectiveness

Efficiency and effectiveness are typical terms used for evaluating the performance of an organization. They are often used as synonyms despite the differences behind the meanings of the terms. The difference between them appear particularly when speaking of a supply chain and the performance. Effectiveness is about doing the right things, while efficiency is when you do things right (Goh, 2013).

By being effective, you produce what was expected and achieve the goals that has been set, but not necessarily with the optimal approach. To describe a process as effective is possible even if the costs are high and the pace is relatively slow. It basically expresses if something is done or not, but not how it is done. Benchmarking and outsourcing are methods for manage the effectiveness of a company (Ibid.). The effectiveness is also affected by how the OTD process is structured, hence, sustainability and long-term plans are preferable.

Efficiency, on the other hand, is about choosing the right approach to do things. Being efficient often involves working at a higher pace and lower costs, optimizing the available resources that are being used in the process. By using the resources in the best way possible, the output of the work will be higher in relation to the input (Ibid.).

To become productive, both efficiency and effectiveness are desirable features in a business and should be balanced in an appropriate way. The combination of the two different terms, describing how a company performs, is shown in Figure 3.

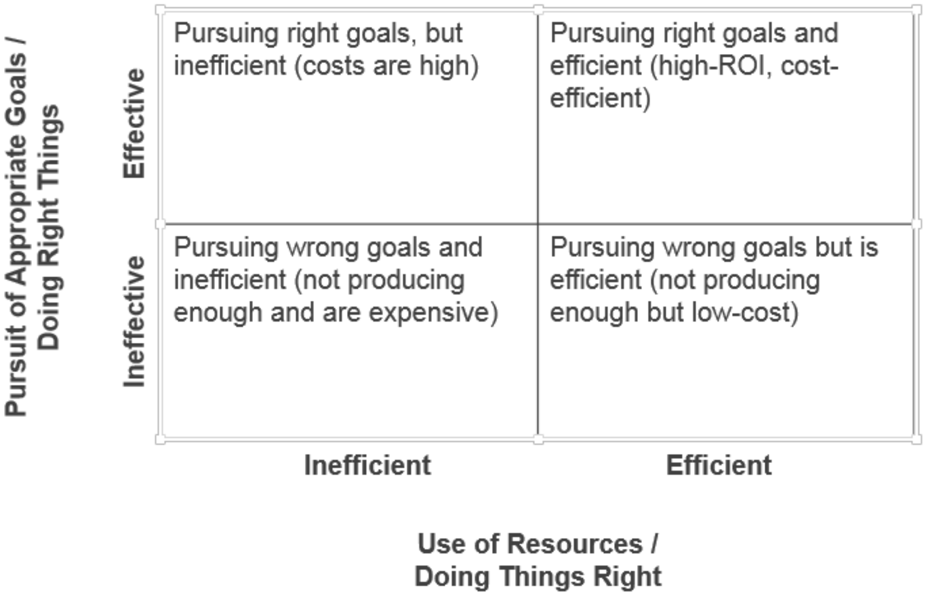

Figure 3. The difference between the terms efficient and effective (Goh, 2013).

3.1.4 Push, Pull and CONWIP

The work in a company can be planned according to different concepts. Push and pull systems involve controlling the work in process that eventually effects the inventory, which in turn has an influence on the performance of the order to delivery process and the overall organization. The two mentioned systems do not have to be mutually exclusive, although they are directed by different approaches (Spearman, Woodruff & Hopp, 1990). Push and pull strategies are often misinterpreted, perhaps due to the naming of the concepts, and could both be driven by customer demand and information flow in both directions. A pull production can produce make-to-stock, for instance by producing an amount of stock in advance based on the usual demand, which contradicts the typical definition of a pull system (Roser, 2015).

The actual difference between a pull and push production system is explained by Hopp and Spearman (2004) as follows:

” A pull production system is one that explicitly limits the amount of work in process that can be in the system. By default, this implies that a push production system is one that has no explicit limit on the amount of work in process that can be in the system.”

Meaning that although a push system has an unspecified upper limit for work in process, a pull system has an expressed limitation on the work, that does not necessarily use the full capacity constantly. A pull system is characterized by downstream processes that are controlled by upstream activities. A push system often has high resource efficiency while a pull system tends to focus on the flow efficiency. A tool to improve the flow efficiency is implementing Kanban in the pull system, to control what triggers and limits the activities in a company, which improve the resource efficiency at the same time (Spearman & Woodruff, 1990).

CONWIP (Constant work in process), is similarly to Kanban, a pull system controlled by signals. The limitation of the Work in Process (WIP) in a CONWIP system is set on the total work in process, not for individual work stations. In other words, the limit of WIP is a constant, therefore the name "CONstant Work In Process". Additionally, the pulling of work in a Kanban system occurs between individual work stations, unlike CONWIP that allows the first work station in the line to pull work (Elkins, Marek & Smith, 2001).

By implementing a pull system, employees can pay attention to a limited number of work items, which makes the company more adaptable to changes, resource efficient, productive and flow efficient. By optimizing the resources in this approach, overproduction can be prevented (Kanbanize, n.d.).

The ability to rapidly adapt to changes is beneficial when controlling inventory and planning the work according to customer demand. Incorrect demand forecasts and order batching can lead to the bullwhip effect, which means that variation in the demand forecasts can lead to imbalance in the supply chain. The whip refers to the reaction in inventory levels and other parts in the supply chain, caused by fluctuations in customer demand. The fluctuation can initially be relatively small, but as the information moves further up in the supply chain, the reaction to the fluctuation gradually becomes bigger. An increase in demand with a number of products leads to an increase in the production, which in turn leads to ordering even more material, and so on (TradeGecko, n.d.).

3.2 Planning and Control

A manufacturing company, just like any other company, needs co-ordination of the activities in different aspects. Jonsson and Mattson (2009) divides the management into three different levels: strategic control, tactical control and operative control.

Strategic control involves the assessment of the current state to maintain and improve the competitive position of the company, in an effective way. It also aims to optimally allocate the total amount of resources and forming successful strategies in the supply chain to achieve the goals of the company. It includes making decisions about locating facilities at optimal sites and distributing the production in terms of location, product mix etc. The responsibility of forming an appropriate supplier structure and choosing between delivering directly to order or from stock also belongs to the strategic control. These are factors affecting the supply chain of the organization and its products and is therefore connected to the management of the OTD process.

Tactical control is the second level of control, which operates according to the framework founded by the strategic control and involves planning the usage of the capacity and designing the production layout. Deciding whether to have a push or pull oriented production system falls under the same level of control. At this level, details within the OTD process and the supply chain can also be controlled, to optimize the resource and flow efficiency of the company.

Operative control is the level of control which regulates the elements within the previously named control areas. It is about continuously directing the daily activities and other short-term issues. The planning of everyday manufacturing and observing deliveries are included in this level of control (Jonsson & Mattson, 2009).

To achieve the objectives with the division of the planning into three levels, they have to involve cooperation between the levels in a way that each planning level operates according to the arrangements founded by the level above itself. There should be well organized interaction between the levels, as illustrated in Figure 4. It is also crucial for the levels to design solutions that are transferable to the levels below, i.e. consider the realization of the decisions and the possible approaches to perform the tasks (Jonsson & Mattson, 2009).

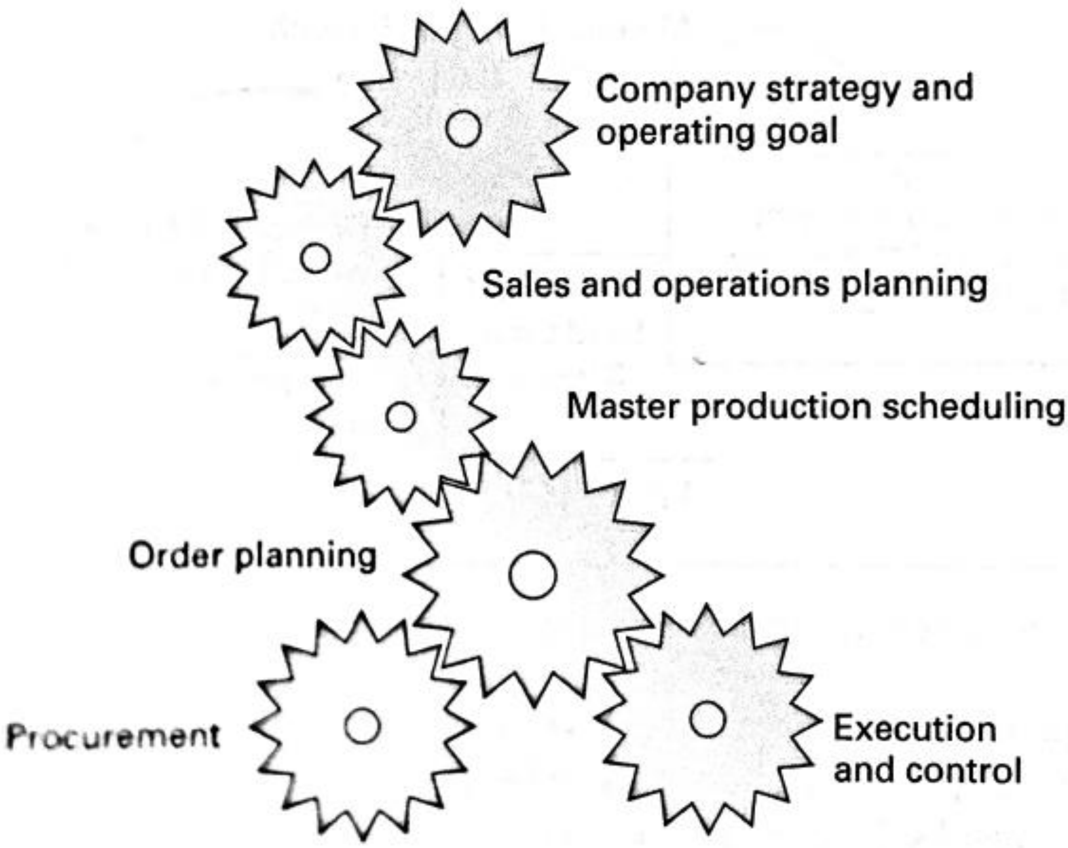

Figure 4. An illustration of the relationship between the levels of planning

3.3 Performance

It goes without saying that every organization wants to perform well and be in the best shape possible. It is necessary to deliberately and continually monitor and improve the performance of a company to become and stay competitive on the market. There are various factors influencing the performance and probably as many approaches to measure it, since different functions aim for different achievements.

The definition of performance, according to the business dictionary, is: “The accomplishment of a given task measured against preset known standards of accuracy, completeness, cost, and speed. In a contract, performance is deemed to be the fulfillment of an obligation, in a manner that releases the performer from all liabilities under the contract.” (BusinessDictionary, n.d.).

Ax, Johansson and Kullvén (2009) describe performance as accomplishments or future accomplishments, in other words, how the company is performing or will perform in the future. The performance and the outcomes are evaluated and measured by different kinds of measures in terms of numbers and descriptive indicators. To get a comprehensive evaluation of the performance, it needs to be assessed on different levels and areas in the business.

There are numerous performance measures intended for different areas and for describing a business from different perspectives, and Parmenter (2015) has divided them in four types of performance measures that fall into two bigger groups, namely *result indicators* and *performance indicators*. Result indicators gather the measures that often describe the performance of several teams together, which are good for evaluating the collaboration between teams, but difficult for identifying one team’s efforts. The two types of measures belonging to this group are Key Result Indicators (KRI) and Result indicators (RI), whereof the difference is that KRIs sum up the performance of the organization and RIs describe the results coming from the different teams’ collaboration. To measure the performance of smaller parts of the business, such as specific teams, there are more suitable metrics that Parmenter (2015) refers to as performance indicators. This group of performance measures include Performance Indicators (PI) and Key Performance Indicators (KPI). PIs indicate what the teams are bringing to the company and KPIs reflect the performance of the organization in terms of critical achievements.

The performance of an OTD process can be presented with different measures; lead time and flexibility are two of the factors affecting that, although it is important to also focus on the approaches and long-term strategies that eventually result in improved performance according to the metrics (Brabazon & MacCarthy, 2017).

3.3.1 Measuring Performance

Key Result Indicators (KRIs) describe the overall performance of a company and include measurements of profits, customer satisfaction, return on capital employed and employee satisfaction. KRIs can be both financial and nonfinancial measures.

To describe the combined effort of many teams, Result Indicators (RIs) are used. They differ from KRIs since KRIs focus on the activities whose results are measured by RIs. Parmenter (2015) states that financial performance indicators measure outcomes of different activities and therefore categorizes them as Result Indicators. “Sales made yesterday” and “Number of staff trained to use specified systems” are both examples of Result indicators.

Performance Indicators (PIs) describe a team’s efforts and are nonfinancial indicators that does not determine the fate of a company but support Key Performance Indicators in describing the company’s performance. PIs could be “number of late deliveries to customers” and “number of innovations implemented by each team/division”.

Key Performance Indicators (KPIs) are the most known indicators that also are crucial for the performance of a company, hence the term "key" in the word. They should be monitored at least weekly and are not expressed in financial terms (like RIs). KPIs can be traced to a single department and are very important to the success of a company, which is the reason why the CEO needs to observe them. "Late deliveries to key customers", "list of late projects" and "Complaints from our key customers that have not been resolved within two hours" are examples of KPIs.

To understand how the four types of indicators are related to each other, an onion analogy which is shown in Figure 5. can be studied. The layers of the onion represent the different indicators and the surface layer of the onion symbolize KRIs that shows the overall shape of the onion that is affected by the nourishment it has gotten. The middle layers that the arrows are pointing towards represent both PIs and RIs, and the core of the onion is where the KPIs are (Parthasarathi et al., 2013).

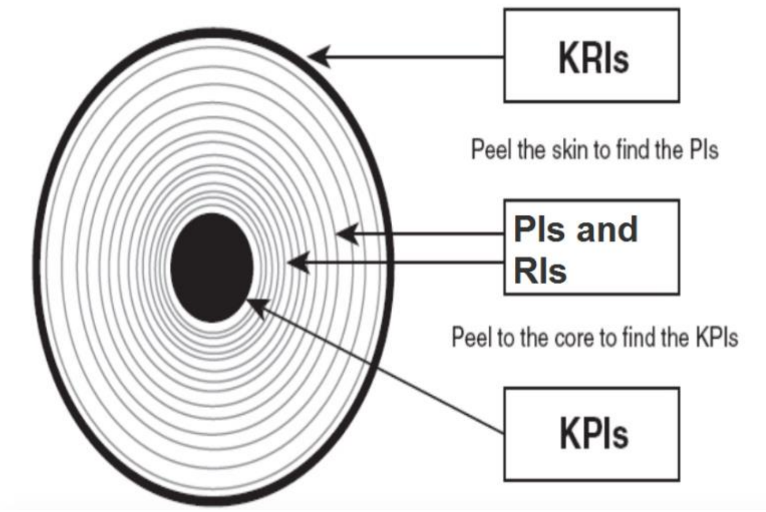

Figure 5. Illustration of the onion analogy explaining the connection between different result indicators

A summary of the indicators is presented in Table 1. where the characteristics and concepts of them are explained. The different indicators require different amount of attention with varying frequency and have a recommendation of how many indicators an organization should measure and monitor.

To not exaggerate the number of measures, the indicators can be standardized since the same indicator can appear in different variants. Parmenter (2015) suggests a 10/80/10 rule to follow as a guideline, which implicates that number of KRIs should be up to 10, 80 RIs and PIs and 10 KPIs. The number of indicators used by the organization can also depend on the magnitude of the operations in terms of number of involved parties and companies.

Table 1. Summary of the four indicators (KRI, RI, PI, KPI) (Parmenter, 2015).

Indicator	**Characteristics**	**Description**	**Number of indicators**	**Timely**
Key Result Indicator (KRI)	Financial and nonfinancial	▪ Summarize a company's historical performance ▪ Useful for evaluating performance of the management	Max. 10	Monthly, quarterly
Result Indicator (RI)	Financial and nonfinancial	▪ Performance of multiple teams	Approx. 80	24/7, daily, weekly, biweekly, monthly, quarterly
Performance Indicator (PI)	Nonfinancial	▪ Indicates how individual teams are performing ▪ Not crucial for company's survival ▪ Support teams to achieve goals according to strategies	Approx. 80	24/7, daily, weekly, biweekly, monthly, quarterly
Key Performance Indicator (KPI)	Nonfinancial measure	▪ Indicate what needs to be done in order to increase performance of the company	Max. 10	Frequently, 24/7, daily or weekly

Different levels in the supply chain hierarchy (Chapter 3.2 Planning and Control) and the various approaches to measure performance all interact with each other and is illustrated in the performance pyramid in Figure 6. The financial and nonfinancial performance is the result of the combined efforts from the long-term strategy of a company and the daily operations. The performance pyramid aims to guide the measurement of performance by dividing it into nine dimensions. The nine dimensions include different perspectives on the company's performance, i.e. overall goals of the company at the top of the pyramid and also individual ambitions (Knowledgegrab, 2019).

The objectives are linked to both external effectiveness and internal efficiency, and the measures are connected to each other horizontally and vertically seen in the pyramid. The objectives influence one another upstream and downstream and an example is that delivery time affect customer satisfaction, the amount of waste impacts the productivity etc. (Ibid.).

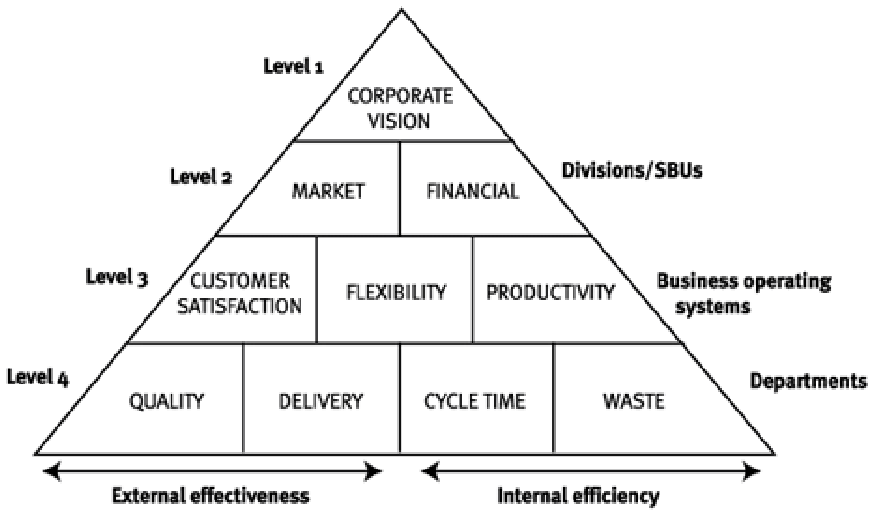

Figure 6. The performance pyramid (Knowledgegrab, 2019.).

The pyramid also distinguishes internal objectives (cycle time, waste) from the external ones (customer satisfaction, delivery) while it connects the hierarchic perspective on the performance with the evaluation of the operations of the company. Knowledgegrab (2019) presents the theory formed by Lynch and Cross (1991) which states that the performance measurements should follow three guidelines. The first one says that the processes in a company should be aligned with the overall strategies. The departments in a company should know what they are doing to influence the achievement of the goals, and how. Guideline number two states that accurate information in both financial and nonfinancial variants should be presented to all levels of the company to support their decision making. The third and the final guideline is to develop a kind of a business that aims for customer-based operations. The three named arguments are the base for the performance pyramid which can guide organizations in developing a new system of performance measuring or alter an existing one Knowledgegrab (2019).

3.4 Lean

"Time is the only resource that you can't buy more of. You can buy machines, hire more people, but time is finite… 24 hours in a day with no possibility of increasing that. The only way we can 'get' more time is to eliminate nonvalue-adding activities that consume some of our 24 hours. This accomplishes two things. It compresses the lead time for satisfying customer demand and frees up time (capacity) for more value-adding activities needed for increasing demand (growth)." (Ballé, 2018).

Lean is a philosophy that can be applied to almost any area in the world, it can be used by companies, in the household, in your thinking and so on, to make the most out of the available time. In order to achieve effectiveness and competitive advantages for any firm, *Lean* thinking can be adapted as an approach to manage and organize different operations within an organization. It was originally derived mostly from the Toyota Production System (TPS) that is intended to optimize the manufacturing process by focusing on improving the value flow, which results in elimination of waste, in other words, activities that does not create value for the customer. It aims for efficient and effective OTD processes, also called Order to Cash, to decrease the waiting time for customers and also for the company that is waiting for a payment.

As illustrated in Figure 7., Lean is an operational strategy that is based on values, principles, methods, tools and activities. All four levels in the illustration together guide an organization to implement the Lean strategy. Values represent respect and cooperation in the organization, principles are the mind-set of the organization (e.g. Just-in-Time and Jidoka), methods define the actions (e.g. value stream mapping), and tools and activities are used to implement a lean operational strategy, as by using 5S. A development of a continually growing organization is also the aim of Lean implementation (Womack and Jones, 2003).

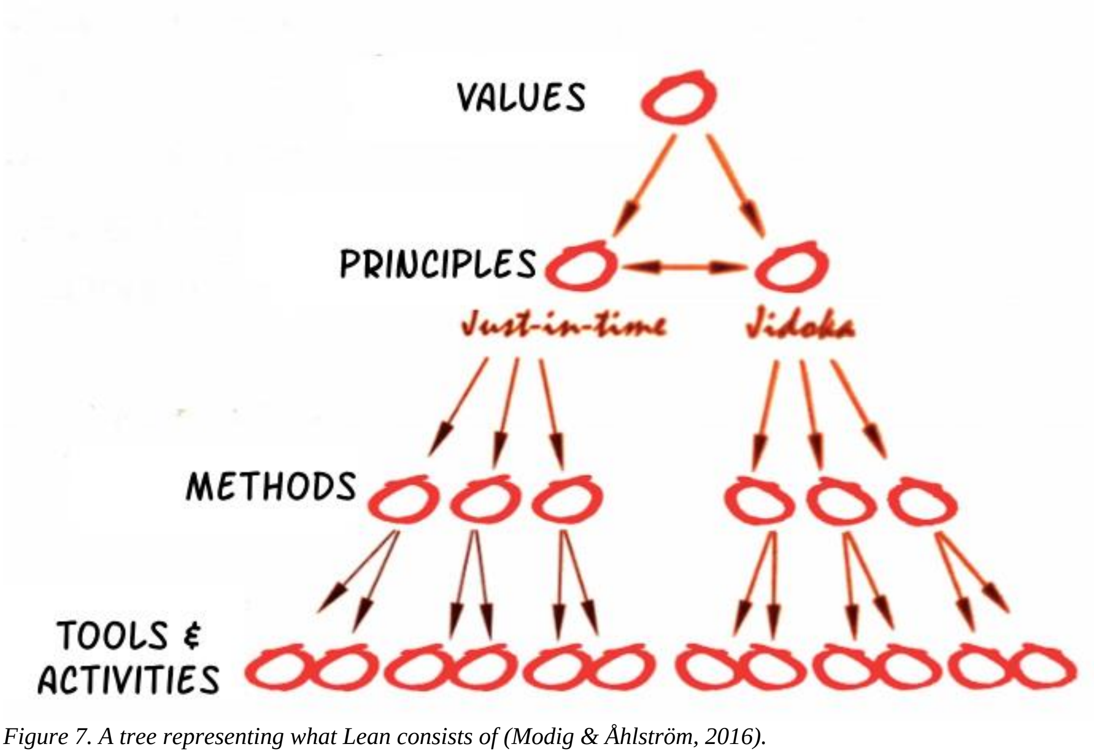

Figure 7. A tree representing what Lean consists of (Modig & Åhlström, 2016).

However, the philosophy behind Lean can be applied to other areas, such as the supply chain, product development, offices etc., to develop efficient and successful companies with continual improvement. As the name suggests, Lean is about making firms *lean* and slimming down processes to achieve more. To do this, the optimal, value creating, way of working, needs to be developed in order to identify and eliminate the wasteful activities, which in turn can be either eliminated or converted into value adding activities (Ibid.).

Lean thinking can be used for process and flow improvement by increasing value in the overall process, and therefore preventing waste. Before attempting to do that, it is beneficial to start with defining value. Value is defined by the customer and created by the producer. What usually clouds managers vision from understanding the true concept of value creating, is the financial mindset that aspire to satisfy stakeholders. They often get distracted by numbers and short-term economic goals, that involve cost cutting through layoffs, adjusting of prices etc. When sales are not going as expected, the usual reaction is to lower the price or add special features to the product, instead of contemplating reshaping the definition of value from the customer’s point of view (Ibid.).

Poppendieck (2002) states that a common problem in Lean implementation is that gaps may arise between different departments within the organization, due to big divergence in measuring the performance. The performance indicators used in the different departments are in some cases not at all related to each other, which leads to difficulties in working unitedly towards a common goal. Performance measured with productivity in one process could mean excessive inventory in the next process, which decreases the overall performance for the company.

To succeed with implementing Lean into an organization, there needs to be an understanding that it requires a change of mindset, since it is not a simple toolbox that can be used for a quick fix. Lean is a philosophy that is composed of tools, principles and a mindset. All employees should be motivated to contribute to the continuous improvement work unitedly, to maximize the value added to the customer. Reinforcement of the philosophies by the management will result in higher performance for the employees. The organization can improve the OTD process via directions and strong support from the management (Liker, 2004). Additionally, except changing the processes and the products, the individuals working at the companies need a shift in perspectives and behavior to achieve good results (Berglund, 2010).

Since Lean philosophy advocates recourse efficiency, a desired outcome is to lower the opportunity cost, which is the economic loss resulting from not utilizing the maximal potential of the recourses. For instance, hiring fewer employees based on the workload, and investing the saved amount in something else (Modig & Åhlström, 2016).

3.4.1 Value

By focusing on value creating, waste can naturally be reduced, and the value delivered to a customer can be maximized. In order to make a profit, a company must create value for its customers, but firstly, value itself needs to be defined to be able to identify the customers’ needs. It is important to always view value from the customers’ perspective (Modig & Åhlström, 2016). Value can be defined as: “The extent to which a good or service is perceived by its customer to meet his or her needs or wants, measured by customer's willingness to pay for it. It commonly depends more on the customer's perception of the worth of the product than on its intrinsic value.” (Businessdictionary, n.d.).

Many companies tend to hang on to traditional approaches to define value, which counteract the evolving of new definitions of value creating. Cost reducing, customizing products to increase diverseness and faster delivery etc. are the usual targets for companies doing makeovers. The mistake of only suboptimizing parts of a value chain could lead to an even more ineffective OTD process. Over again, value must be seen from the customers point of view. The difficulty of knowing precisely how to meet the customers' needs, could be due to the focus on the operations of the own firm. It is not unusual for value to go through multiple companies, for instance when it comes to travelling by plane. The traveler is involved with a number of companies to get from A to B. The process could start by booking transportation to the airport, sometimes several hours ahead. The activities at the actual airport are in turn connected to multiple different functions, and in some cases separate companies. When the person finally arrives to the final destination, the activities that the traveler has gone through often reach across functional boundaries, considering check-in services, customs, airport shops etc. To maximize value for a traveler, the entire value chain needs to be analyzed, i.e. focus on the whole product or service (Womack and Jones, 2003).

To redefine value, companies have to evoke new ways of thinking and communicating with customers and other companies. By continually developing and improving, firms will be able to broaden their customer base and grow in several aspects. This continuous improvement is called *Kaizen*, which is a Japanese term (Ibid.).

A significant step in value identification is finding the *target cost* for the product, which is the sum of all used recourses, excluding *Muda*, i.e. the wasteful activities. By doing that, it becomes visible for companies what they actually are spending on a product, since every step in the process contribute to the total cost of the product, which motivates for finding the sources of waste (Womack and Jones, 2003).

3.4.2 Muda – Waste

Muda is a Japanese word for waste, which is, from a Lean-point of view, activities that consume resources that do not generate value for the customer. inefficient processes that carry *Muda* can be found in any business field and could be related to producing more than needed which leads to excess inventory, unnecessary motion of people and items, waiting time because of unsynchronized processes, products with low customer satisfaction etc. (Womack and Jones, 2003).

Seven types of *Muda* were identified by Taiichi Ohno (1912-1990), the Japanese Toyota engineer that was one of the leading designers of the Toyota Production system that later on developed into Lean manufacturing. An additional type of *Muda* has been identified except the seven first, and all of them becomes visible from a Lean perspective (Ibid.). The eight types of *Muda* are summarized in Table 2. with corresponding examples from office environments.

Sources of waste exist in offices as well, as in production facilities. The types of waste in an office can be categorized similarly to manufacturing waste and is presented in Table 2. Many of the office processes are not directly connected to the customers, which makes it more difficult to comprehend when value is created. The performance in the production can explicitly be measured based on the ongoing situation and monitored while adjusting parameters to eventual changes (Keyte & Locher, 2004).

Table 2. Costly office wastes that are not value adding for the customer (Keyte & Locher, 2004).

Waste Category	Office Examples
1. Overproducing Producting more, sooner, or faster than is required by the next process	Printing paperwork out before it is really needed, purchasing items before they are needed, processing paperwork before the next person is ready for it
2. Inventory Any form of batch processing	Filled in-boxes (electronic and paper), office supplies, sales literature, batch processing transactions and reports
3. Waiting	System downtime, system response time, approvals from others, information from customers
4. Extra Processing	Re-entering data, extra copies, unnecesary or excessive reports, transactions, cost accounting, expediting, labor reporting, budget processes, travel expense reporting, month-end closing activities
5. Correction Any form of defects	Order entry errors, design errors and engineering change orders, invoice errors, employee turnover
6. Excess Motion Movement of people	Walking to/from copier, central filing, fax machine, other offices
7. Transportation Movement of paperwork	Excessive email attachments, multiple hand-offs, multiple approvals
8. Underutilized People People's abilities, not their time	Limited employee authority and responsibility for basic tasks, management command and control, inadequate business tools available

1. Overproducing

Overproduction is a waste since it involves producing a larger quantity than demanded and at the wrong time. This type of imbalance can be the result of producing too large batches, inadequate relations with suppliers, long lead times etc. The inventory piling up due to overproduction is an expensive factor for firms and could be solved by following the principles of Just in Time (JIT), which guides firms to produce the right quantity at the right time (The Seven Wastes, n.d.). As stated in Table 2., the waste of overproducing can also be an issue in an office environment, an example of that is any wrong timing of work which leads to material that is not needed at the time, i.e. unnecessary paperwork printing, buying products too long ahead and not prioritizing work right (Keyte & Locher, 2004).

2. Inventory

Every item in the inventory carries costs that are accumulating until the piece is handed over to another part that is responsible for it. The cost comes from the price for storage and from handling the product in different ways. Further, the items will also need internal transportation which comes with a risk of damages. This type of waste includes several other types of waste and both direct and indirect costs (The Seven Wastes, n.d.). Administrative processes have other kinds of inventory, according to Table 2., for instance, physical or electronic mailboxes, excessive office supplies etc. that also indicate that there is room for effectivization. The lack of space due to big volumes of unneeded things is also *muda* (Keyte & Locher, 2004).

3. Waiting

The waiting time during communication between different departments, suppliers and other external parts is another one of the eight wastes. Long waiting times can also be found between different activities in the production and maintenance of machines. Excessive waiting disturbs the flow in the work and could be a sign that some process is ineffective (The Seven Wastes, n.d.). Waiting time in an office occurs when IT-systems fail, or the responses are delayed, waiting during internal and external communications etc. (Keyte & Locher, 2004).

4. Extra Processing

Over processing is a costly error in terms of money and time. It involves using the wrong techniques, inappropriate equipment and processing the product in a way that was not asked for by the customer. A typical example of over processing is the use of an expensive all-around machine that is able to process all kind of products, but with the consequence of disturbing the flow in form of delays etc. From e Lean point of view, small suitable machines are sufficient and preferable (The Seven Wastes, n.d.). Administrative extra processing is connected to non-value adding activities that may be inevitable, such as reporting hours of expenses, redoing work and so on (Keyte & Locher, 2004).

5. Correction

This waste tends to be the most transparent for people, but it can also be hard to notice before the customers. It is also called “the waste of defects” and means, as the name suggests, flaws in the quality leading to defects. Defects cost large amounts for firms since they need to be repaired or replaced. Aside from the obvious direct costs, defects spread plenty of indirect costs such as spending of resources and material, they require additional paperwork and could also lead to lost customers. The ultimate way to avoid this waste is to work on preventing quality errors, rather than learning to detect them. A possible approach to increase quality is using poka-yoke systems and/or autonomation (The Seven Wastes, n.d.). Paperwork can contain as much errors as production, for instance invalid orders or errors in invoices, engineering change orders, unqualified design etc. (Keyte & Locher 2004).

6. Excess Motion

When people or machines move excessively, a lot of time is consumed that could be used for value adding activities. These movements could be due to equipment not being accessible enough which forces the employees to bend down to reach things, which could be solved by placing things at the most appropriate places. The excessive movement of machines and people between stations can also increase the stress level for both employees and the machines (The Seven Wastes, n.d.). Movements in an office environment can also be a waste of valuable time, for instance when employees need to walk from one location to another to the copying machine etc. (Keyte & Locher, 2004).

7. Transportation

Unnecessary transportation of items is an activity that brings no value to the customer and is therefore a costly waste for a firm. This type of excessive movement requires employees to dedicate their time to perform these tasks, that might be avoidable (The Seven Wastes, n.d.). The excessive transportation of items can also be applied to administrative work, for example when emails contain unnecessary attachments, information is sent back and forth with no purpose, and too many parties involved in decision making (Keyte & Locher, 2004).

8. Underutilized People

All employees have some talents that could be embraced to cut down waste. By realizing that they are more than robotic operators, new opportunities could be created (The Seven Wastes, n.d.). Assigning employees with broader responsibility areas and authority to make decisions based on their knowledge could bypass delays (Keyte & Locher, 2004).

3.4.3 Resource Efficiency and Flow Efficiency

Different forms of efficiency exist, and to succeed, they need to be adapted to the firm and an appropriate balance needs to be found between them. Modig and Åhlström (2016) describe resource efficiency and flow efficiency, as two different forms of efficiency. Resource efficiency is traditionally the main focus for many firms, which helps them to utilize their resources as effectively as possible, while capturing value. The usual strategy is to divide the processes in different departments with associated responsibility areas, which has been profitable in means of economies of scale. This philosophy dominates in many industries regarding leadership and organizing of the firms and is a useful approach to decrease the opportunity cost. However, despite the advantages of resource efficiency, it is not always the ultimate performance indicator, since it does not describe the flow and can lead to overproduction. Individual resource efficiency can, according to Novkov (2018), be measured by dividing the active working time with total available working time and multiplying by 100, to receive the percentage form of the person’s efficiency.

In contrast, flow efficiency focuses on the product or service moving in the flow, to minimize lead time and add maximal value to the customer. This type of efficiency tends to generate more value to the customers since every working unit, in the order to delivery process, is focused on finishing one product or service. By focusing on completing one product/service, the quality may be enhanced due to the concentrated efforts. The flow efficiency is measured by focusing on the value adding time to the customer and dividing that with the total lead time (measured from order to delivery). That amount multiplied by 100 result in the flow efficiency in a percentage form, where the median flow efficiency usually falls under 20% (Novkov, 2018).

Finding the right balance of resource efficiency and flow efficiency is important to form a well-functioning organization, although many firms focus on resource efficiency. This may lead to negative effects like excess work and less focus on the customer. Combining the different forms of efficiency within an organization is difficult and the ratio can be demonstrated by different laws. Little’s Law states that the number of units included in the flow is directly related to the throughput time. Throughput time is also affected by bottlenecks, which is described with the bottleneck law. The law says that the most time-consuming step in the process has the highest impact on the throughput time. Those steps are often bottlenecks and they are distinguished by finding the steps in a process that has the lowest throughput and disturb the flow (Modig & Åhlström, 2016).

The aim for organizations is to find the perfect state between high resource efficiency and high flow efficiency, since both types are necessary, and they need to comprehend the relation between them. *The law of the effect of variation* describes how variation in the processes affect the flow efficiency. The variation is found in resources, the product or unit going through the flow and external factors, among other things. The performance of machines and people deviate depending on countless reasons, the processed units in the flow require different operations and external factors like unpredictable events, can altogether have an impact on the flow efficiency.

The law of the effect of variation states that the throughput time increases with the level of variation in the process, given that the resource efficiency is kept constant. It also states that the closer to 100% utilization rate (also seen as resource efficiency) you get, the longer the throughput time (Modig & Åhlström, 2016).

Furthermore, both types of efficiency are significant, and an optimal state can be found by initially visualizing the workflow with different tools. VSM and Kanban boards are suitable tools, whereof a Kanban board is built by organizing all activities on a sheet/wall, with different columns separating the status of the task, e.g. “to do”, “in progress” and “done”. Since Kanban actually is a signal, it is applicable for administrative work and pursues the just-in-time principle. The second action to increase efficiency is limiting the work in progress (WIP). By having a boundary for the number of tasks in progress, and therefore not starting new activities that exceed the boundary, the utilization of resources will become more efficient and it is also beneficial for the flow efficiency. Setting the level of the limit will define what type of efficiency is the focus and the optimum for a specific organization can be found by observing how the performance indicators relate to different settings (Novkov, 2018).

3.4.4 Lean Office

The administrative processes represent a significant share of the entire OTD process, and the majority of these processes occur in an office environment. Working towards a culture with continuous improvements and constant focus on the value flow is an approach to shape a Lean office and it is described further in this subchapter.

Waste can not only be found in the manufacturing processes, but also in the office environment, and it can cause delays due to waiting times and a long chain of decision makers etc. The Lean principles and tools can be applied to offices, but before doing that, the process needs to be understood to be able to trace the sources of waste. It is important to assess the entire flow of activities related to a product, to measure the lead time from order to delivery (Asefeso, 2012).

Lean aims to shorten the time measured from customer order to delivery, which means that the entire lead time from the customer’s point of view. The process is affected by several parties including product development, supply chain planners, sales and purchasing divisions, order processing and so on. To visualize the process and to find wasteful steps, they need to be mapped. The steps then need to be analyzed in order to understand how they are related to each other and how they can be optimized as small components in an entire flow. The objective is to find out how to, in the best way possible, conduce a more efficient flow, and not to sub optimize the individual steps. Areas where delays and waste might occur are for instance in administration of orders, since the data can contain errors, the work could need standardization and customers are waiting. Engineering change orders are potential bottlenecks since they can involve long waiting times due to several decision makers, several meetings and unevenly distributed work, that slow down the process. Waste in the ordering process can take the form of data errors, inadequate procedures related to approving orders. These steps can be optimized and slimmed down with lean thinking by allocating people and tasks differently (Asefeso, 2012).

3.4.4.1 Office Efficiency

Inefficiency caused by bureaucracy, high volumes of paperwork, waiting time etc. in the administrative processes can lead to unmotivated employees and low productivity, and it can also slow down other processes. With Lean thinking, the office performance can be improved without layoffs and cutting corners in means of resources. Firms should encourage employees to focus on value through the eyes of the customer and therefore shortening the lead time by minimizing idle time between decision making and excessive paperwork. The motivation of employees is another broad topic that includes several different elements including having the suitable knowledge for the job, having authority for decision-making in some extent etc. The objective for Lean thinking is to provide the customers with good service, which is done by delivering what the customers want at the right time (Asefeso, 2012).

The implementation of Lean onto the administrative processes can be done in a similar way like to manufacturing. Engaging everyone working in the office is a good starting point while leaders need to be dedicated to the project, since the process requires time and other resources. Visualizing the processes in form of a Process Map and Value Stream Map (VSM) highlights the activities, the time consumed and the waste. The next step is to plan a future state where the waste is eliminated and follow the plan by integrating it into the mindset of employees (Asefeso, 2012). The concept of VSM is explained further in Chapter 3.5.

3.4.4.2 Office Metrics

Most of the production process metrics can be reused for administrative processes. A selection of the metrics that can be applied to offices, altered by Keyte and Locher (2004) is presented below:

- *Lead time* - the total time it takes to complete a process including waiting, errors and the process time. In administrative processes, lead time starts from the time when the work is available until it is handed on to the next process and includes the delays that occur in between.

- *Process time* - the (active) time it takes to actually perform an activity uninterrupted, i.e. plan an order, excluding waiting time etc.

- *Value added time* - time spent on the actual value adding activity

- *Changeover time* - time required to adjust from one way of working to another, i.e. changing product type or task, exchanging paper in a printer to a different type etc.

- *Typical batch sizes or practices* - how frequently a specific task is completed or in what quantities, if it is done once a week, the batch size is of one week

- *Demand rate* - measures customer orders per day, shipments per day etc. to create a working plan based on the customer demand

- *Percent complete and accurate (% C&A)* - percentage of accurate electronic or paperwork received without the need of rework

- *Reliability* - proportion of available time that the equipment works as expected

- *Number of people* - could be either the number of possible employees with the right knowledge, or the number of people working full time with the process

- *Inventory* - in an office, inventory normally represent electronic information piling up and affecting lead time

3.4.5 The 5S system

One of the tools used in Lean to achieve good results is following the 5S system that guides firms to organize their work according to Lean principles (Black 2008). Offices undergo constant transformation of work procedures due to the change in the environment. The competition on the market forces companies to develop in terms of product variety, more complex technology, and the employee turnover can increase, which means that standardized and organized work is important for the companies to succeed. Since offices need to develop constantly, the wastes need to be minimized to be able to perform good work. Teamwork is required to achieve results instead of trusting a few employees to solve any problem. The 5S system helps the company to respond quicker to the market which makes it stronger and reduces the 8 wastes described in the previous subchapter (Fabrizio & Tapping, 2006).

The keywords are translated from Japanese and adapted to an office environment as follows:

1. Sort

The first activity is about separating necessary and unnecessary things in the working area, to eliminate distractions and make necessary things more available.

2. Set in Order

Organizing the workplace and letting each item have its own designated place allows people to find what they are searching for faster. This includes marking boxes and files and sorting electronic inboxes to make important things accessible when they are needed.

3. Shine

Shine stands for cleaning the workplace and keeping it clean by setting guidelines for the cleaning process. This activity allows people to detect problems and errors in equipment etc. and makes the area safer and pleasant to work in. It is less time and energy consuming to maintain a decent workplace by continuous cleaning, than to sort out a huge mess.

4. Standardize

This keyword means standardizing the 5S method within the working area, to make the system visible and natural for all employees. The 5S system is meant to be followed continuously during work and by sharing the responsibilities and assigning tasks, the system becomes a standard. The same principles apply for an office environment and should also be used in computer work, for instance creating templates for documents, guidelines for how folders and information is sorted out, and designing clear pictures of what pattern should be followed.

5. Sustain

Well informed and dedicated employees are more able to sustain the 5S system. The guidelines should be followed daily to achieve more efficient work and to support the *Kaizen* (continuous improvement) process, and this is done by follow ups, educating the staff and committed leaders (Fabrizio & Tapping, 2006).

3.4.6 Heijunka

Heijunka is a Japanese word that means leveling and the meaning behind it is frequently referred to in the manufacturing environment. The concept of leveling the production involves designing a production system where the product mix is evened out in terms of volumes and product type. The purpose of it is to improve the flow by reducing considerable irregularities in the production. A steady work flow is preferable to prevent overburdening of the production and the employees and to optimize the resources to meet customer demand. This method allows manufacturers to go from batch production to a more customer demand-oriented production, which enables them to shrink inventory levels and therefore the costs resulting from it. The demand can fluctuate greatly, which leads to the consequence of big variations in the production. By scheduling the production according to a present takt time based on the average demand, the work pace becomes more stable and more responsive for changes (Kanbanize, n.d.).

The production leveling can be done in two different ways: leveling by volume and leveling by type. Volume leveling is related to the pursuit of a continuous flow and evasion of batch production. Naturally, the number of orders fluctuate from day to day and by planning the production according to the average demanded volume, the demand is eventually met without pressuring the processes irregularly. The second type of production leveling is leveling by product type and is also about smoothing out the work load according to the average demand while keeping up with the takt time. Both types involve arranging the work to achieve a smooth flow with less interruptions (Ibid.).

By sending a balanced mix of orders to the factories, the leveling may enable a smooth flow in a pull-oriented production, which result in an even consumption of resources. An uneven consumption can lead to irregular requests to the suppliers, making them unable to supply the production with the optimal volumes at the right time, when it is needed. If the factories produce a number of difficultly manufactured products consecutively, and thereafter a number of products that are considered simple to build, there can occur disturbances in the flow, since the large deviations in cycle times can interrupt the flow at some points. A central factor in a supply chain is the interaction between different entities, which makes Heijunka worth considering by all parties effecting the flow.

3.5 Value Stream Mapping

Value Stream Mapping (VSM) is the methodology used in this study and is therefore described step by step in this theoretical subchapter. VSM is commonly used in the production environment but can be adapted to administrative processes, which is explained further in this chapter.

A *value stream* consists of all activities including non-value adding and value adding, that result in a finished product or service. The value stream is made of the physical transformation from raw material to a product, and the administrative work including the design and financial elements. By looking at the entire value stream, the whole flow of processes can be optimized instead of sub optimizing sections. VSM is about visualizing the value stream by drawing the significant processes, based on the area of interest. Although, the general usage of VSM is within the production area. The method of VSM starts by monitoring the downstream path of a product from the final destination to the supplier and drawing the processes in the material and information flow. Thereafter, an ideal future state is mapped based on a number of questions. The desired result of VSM is to identify wastes and the optimal flow (Rother & Shook, 1999).

Before implementing big changes in a firm, it is beneficial to map the future state to visualize the value stream and to be able to analyze the timescale and sources of waste. The mapping is a tool to see what can be improved. To create a useful map, the product family needs to be defined, in order to avoid confusing and over detailed maps. A family of products is distinguished from the entire range of products, by finding the common denominator in among activities they go through (Rother & Shook, 1999).

Since companies often are divided into different sections, there is rarely a person with an overall view of the value stream. When performing value stream mapping internally without hiring consultants, it is important to start by designating a person in charge, that is responsible for considering the entire value stream. The optimal results will most probably not be achieved by dividing the mapping process between different parties and attempting to combine the parts into a complete map. To sum up, value stream mapping is about mapping the product flow following the steps illustrated in Figure 8., not the firm itself (Rother & Shook, 1999).

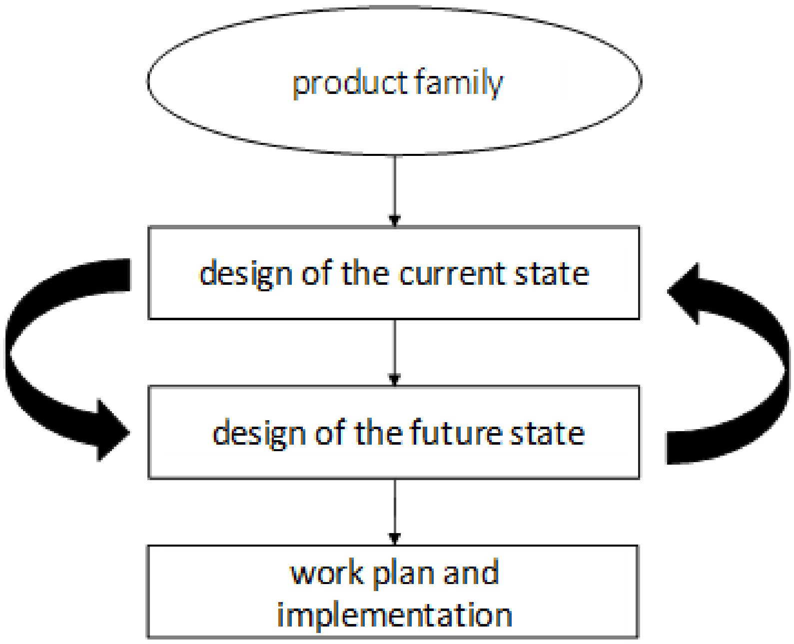

Figure 8. Value Stream Mapping steps (Rother & Shook, 1999).

3.5.1 Current State Map

To find improvement areas to highlight in the future state map, an assessment of the current situation needs to be carried out. Initially, the map should contain general process boxes, that eventually will be developed into several more detailed symbols. Starting out with an overall perspective will allow the value stream manager to decide where to zoom in, to analyze particular activities, or to step back to see the bigger picture including suppliers, transportation etc. The level of details at the beginning should be door to door within the plant and the value flow should be followed by walking through all processes that the product family passes. Documenting information and timing processes simultaneously, instead of relying on available data and old process maps, result in reliable outcomes. The whole process should be mapped by one person/team, with a paper and a pencil, despite several interested participants (Rother & Shook, 1999).

There are a number of icons symbolizing different processes and entities in a value stream map, that together build a complete map. According to Rother and Shook (1999), a good starting point is to place the factory-symbol in the upper right corner, with a complementary data box, as illustrated in Figure 9. The data that is entered is the demanded number of products, shifts etc.

The next step is to plot the process boxes, that represent the processes that the product flows through. Several workstations can be united in one process box, given that they are connected with each other. What unites a number of activities into one separate process box could be the association between the activities. The content in one process is usually coherent in a way that they are done consecutively. The data box adjoining the process box should in turn contain information and metrics that describe the process. The material flow in the value stream map goes from left to right, unlike the actual flow in the plant. Separate flows that are joined at some point can be drawn as parallel process boxes (Rother & Shook, 1999).

The data boxes can contain different types of measures, like the *cycle time* (total time for a process), *changeover time* (time for readjusting the workstation for another type of product), *number of people working* in the process, *uptime* for machines and the *total time available* per shift excluding breaks, meetings etc. Between the process boxes, accumulated inventory is placed with a symbol and representing numbers (Ibid.).

Information flows in the map go from right to left and explains how the processes get information about how, when and in what quantity to produce. Below the flow, a timeline is drawn that separates value adding time and non-value adding time (inventory). The three flows in the value stream map are the material flow, information flow and a timeline, that together complete the map. The timeline is a type of a performance assessment (Ibid.).

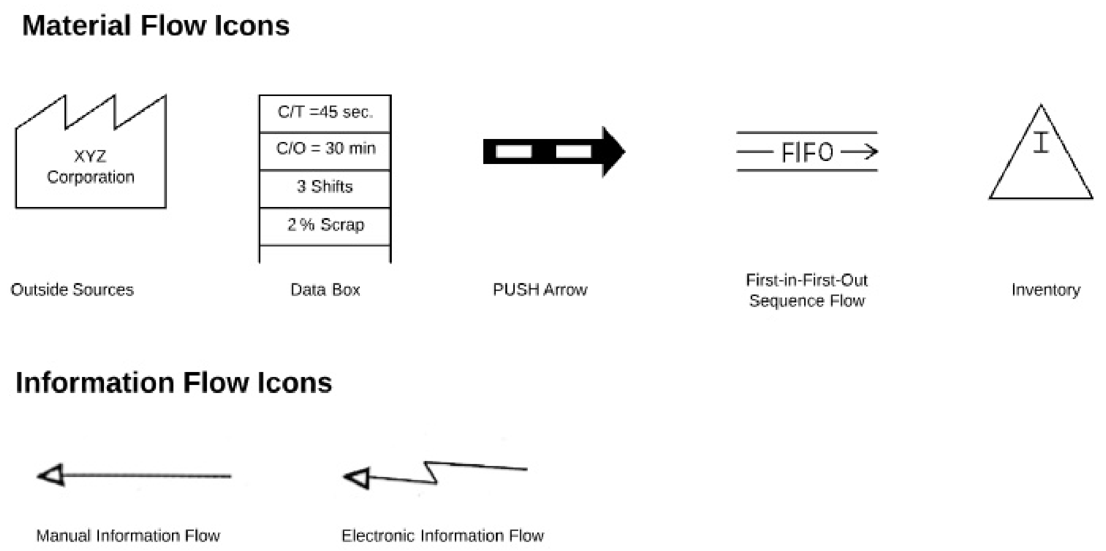

Figure 9. A sample of icons used in value stream mapping (Rother & Shook, 1999).

3.5.2 Future State Map

After mapping the current state, the planning of the future state can begin, to achieve the optimal flow for the company and create maximal value for the customer. To design a future state that is reachable within a reasonable timeframe, eight key questions are formed by Rother and Shook (1999). The timeframe is eligible since the implementation can be divided into several steps. The questions are guidelines to convert a traditional production system to a Lean production system and before asking them, an assessment of the current state needs to be done.

1. What is the takt time?
   The first one implies that the takt time (Available Working Time ÷ Customer Demand) for all processes should be measured to find eventual bottlenecks.

2. The second question is if the company produces to fill up inventories or do the products go directly to shipping. This depends on the customer demand, which can be predictable or unpredictable.

3. Question 3. investigates where implementation of a continuous flow is possible, which should not result in reduced resource efficiency. A continuous flow dedicated to one product family should consist of workstations that are placed after each other, so that the product can be built continuously from station to station, with minimal interruptions. The downside of doing that without further calculation, is if the takt time is significantly lower for one machine, and it is used for other product families as well, the utilization of it becomes inefficient and it might mean that another identical machine needs to be acquired, which presumably is not the optimal approach.

4. The fourth question aims to explore where supermarket pull systems could be implemented, without slowing down the process due to change over time.

5. The fifth question that should be asked is in which process a scheduling point (pacemaker process) should be placed.

6. Question 6. is about the leveling the mix of product types with the objective to minimize the number of errors, lead time and cost for the entire value stream.

7. The seventh question is "What increment of work will you consistently release and take away at the pacemaker process?", which means that the interval where a number of products are processed should be calculated by means of the takt time and number of products.

8. The eighth and the final question when designing the future state is to assess how to improve the process and optimize the value stream. The answer to this question could be, for instance, to reduce the time it takes for changeovers, shortening lead time by arranging some activities differently, eliminating waste that has been found etc.

The eight questions are converted to an office perspective by Keyte and Locher (2004), presented in Figure 10. They are focused on what the customer needs and how frequently, how the company should assure goal reaching, redefining processes according to customer value, how the flow can become smoother by reorganizing the staff and the tasks and finally how the processes should be improved to reach the future state.

Future State Questions

1. What does the customer really need?
2. How often will performance be checked?
3. Which steps create value and which generate waste?
4. How can work flow with fewer interruptions?
5. How will work be controlled between interruptions?
6. How will the workload and/or activities be balanced?
7. What process improvements will be necessary to achieve the future state?

Figure 10. Future state questions adapted to office (Keyte & Locher, 2004).

After designing the ideal future state, the next step is to implement it. The execution should be divided into different steps and the strategy for the future value chain shaped. Starting the course of action, awareness is needed about what is going to be done and when, considering predefined and transparent goals (Rother & Shook, 1999).

3.5.3 Value Stream Mapping for Administrative Processes

The tools of Lean are usually used in manufacturing processes, but can, with some modification, be applied to administrative and office processes. A finished product in the customer's hands is the outcome of all processes within a value stream. Other than the physical transformation (manufacturing), the problem solving, and the information management are inevitable factors in obtaining a complete product, whereof the latter is briefly portrayed in Figure 11. Problem solving involves designing a product that fulfils the customers' needs, and information management connected to the product is about the non-manufacturing steps, including order handling and planning. All three factors including their interface need to be understood by the company in order to assess the performance in terms of quality, cost etc. (Keyte & Locher, 2004).

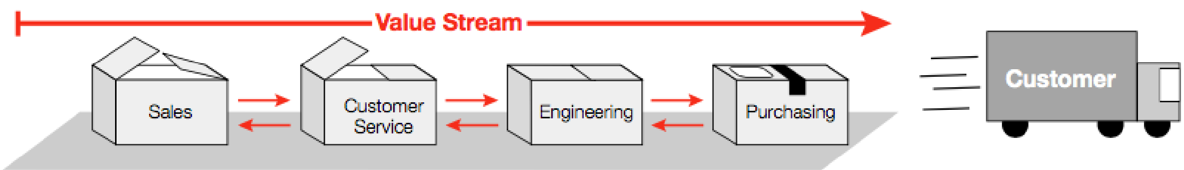

Figure 11. Value stream for the office (Keyte & Locher, 2004).

Some obstacles may arise while mapping the administrative value stream according to the traditional VSM approach described in *Learning to see* by Rother & Shook (1999). Takt time can be difficult to calculate, the implementation of pull and continuous flows is not the same as for production, of mix and volume levelling has different meanings and the measurement of the value stream differs from the non-manufacturing concepts. However, the method of value stream mapping can similarly be used in the office, with some basic differences. The flow of material represents the data flow, both physical and through computers. The information flow that provides information to the processes, to schedule tasks, is found in both office and manufacturing environments (Keyte & Locher, 2004).

The process of mapping could become more complex when moving to a non-production area, since the information flow is more abstract compared to production, and most of the departments/functions are involved in several different processes. Offices are normally divided in departments separated with titles as purchasing, finance etc., which obscures the interaction amongst functions (Ibid.).

Keyte and Locher (2004) describe the information flow as "…the fuel that drives the material flow", which reveals that inefficiencies in the production can possibly stem from the administrative processes. A lean transformation for the entire enterprise is therefore valuable.

4 CURRENT STATE

In the following chapter, the current state of Volvo Penta's OTD process will be described based on interviews with employees at Volvo Penta and the factories in Skövde and Vénissieux. The previously presented theoretical framework was followed as a guideline. The value chain in the current OTD process will be presented starting with Volvo Penta since it is the starting point of the value chain and the only direct connection with the customers. The two engines manufactured by the two different factories go through similar activities, especially the administrative processes, and they are specified in each subchapter. In each process, eventual viewpoints on the current processes and the anticipated affection of Stage V obtained from the interviewees are included.

4.1 Volvo Penta

There are currently approximately 800 employees working at Volvo Penta in Sweden in different divisions all related to the different engines developed and sold by Volvo Penta. The great variety of configurations and components within the engines that the customer can choose from is one of the factors that makes Volvo Penta unique and competitive in the market, despite their small representation within the Volvo Group compared to the other companies, in terms of employees.

The different departments collaborate continuously throughout the process of developing, marketing and step by step delivering the engines. The administrative work takes place primarily at Volvo Penta in Gothenburg and the daily contact with the factories, in most of the cases, is between Volvo Penta and the order offices in Skövde and Vénissieux. The OTD process in this case does not include R&D, purchases and the marketing departments, but they set the base for how the value chain for an engine is designed, and they are therefore described briefly in following subchapters. Additionally, the term OTD (order to delivery) process, in this study, represents the value chain that starts with a receival of a customer purchase order (PO) and ends with a delivery in a hub, where the engines have a stopover before they are shipped out to the final customers. The orders/engines are only followed to the hub due to the big variety in transport types and durations depending on the final destination country.

The Volvo Group has developed a comprehensive process map, VGMS (Volvo Group Management System), to overview the main activities for the Volvo Group companies including Volvo Penta. Volvo Penta as an enterprise can be divided into four core processes as Figure 12. shows. These four core processes include a large number of processes in each box, which are revealed by clicking on the core process in interest, allowing the user to view the next level of the map.

Develop Product and Aftermarket Portfolio (DVP) is the first process, which mainly consists of optimizing Volvo Penta's product portfolio in terms of product development and problem solving in maintenance and quality etc., including maintaining and developing Volvo Penta's brand.

The second core process is Market and Sell Total Offer (MAS), which, as the name suggests, aims to market and sell the total offer. The total offer is a collective name consisting of activities to acquire business partners and customers, with the attempt to create a pull demand. The front office activities are included in this core process which involves having direct contact with customers and business partners. In this process box the customer purchase order is entered, and the orders are planned and firmed, which means that the production planning is triggered when this process finishes.

The planning of the supply chain considering resources, capacity, transportation and the production lead time, belong to the process box named Produce and Distribute Products (PRD) in Figure 12. This is where the Back Office and the belonging departments' activities are found.

The fourth and the final core process in Volvo Penta is Deliver and Develop Customer Loyalty (DCL), where the customer relations are sustained by supporting them in case of change requests, need of repair services and complaints.

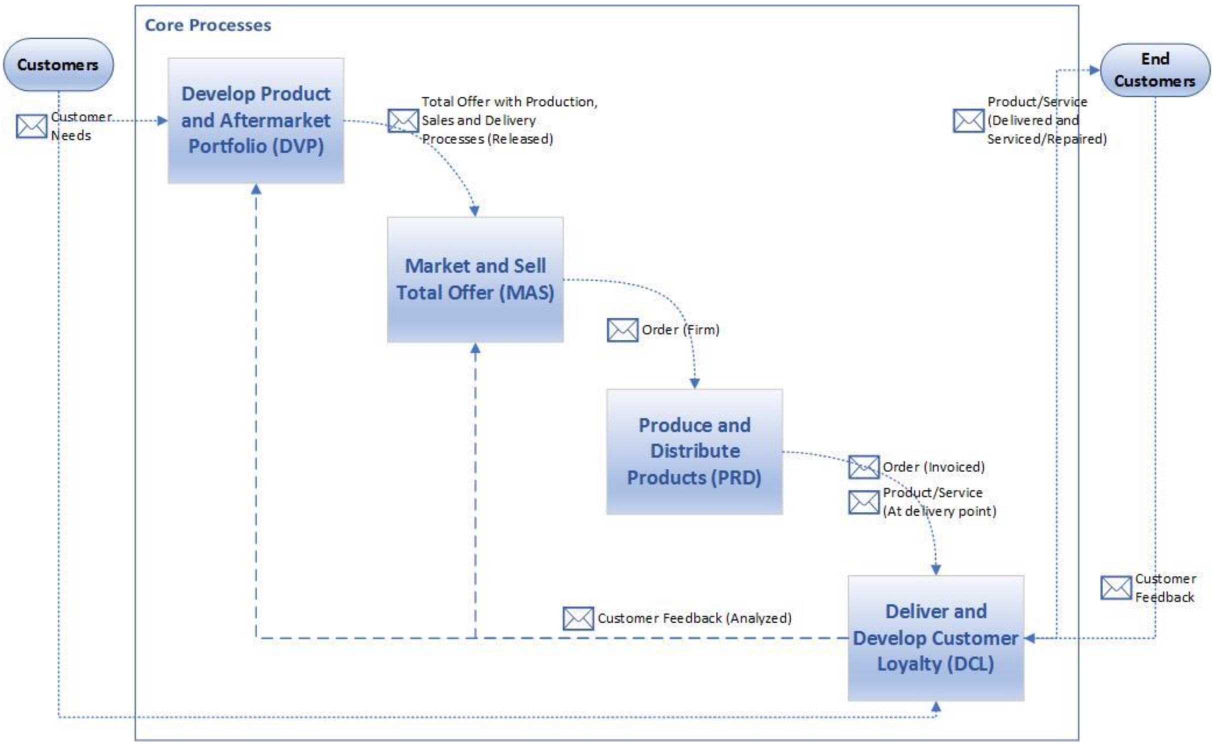

Figure 12. The four core processes for Volvo Penta

4.1.1 Product Development

The product development departments at Volvo Penta are separated by different engine sizes. Low Duty Engine Platform (LDEP), Medium Duty Engine Platform (MDEP) and High Duty Engine Platform (HDEP) are the three divisions responsible for designing the engines. In this study, the value chains of the industrial engines D11 and D13, which belong to the HPED division, are examined. Since Volvo Penta develops industrial, marine and versatile engines with several different sizes, the two engines that are mentioned here are a small fraction of the entire value flow of the products. This means that all the mentioned divisions work with several different engine types and sizes, and customers from different regions. HDEP develops, except from D11 and D13 industrial engines, the marine and versatile variants of them, and also engine D16 for all three areas of application.

At Volvo Penta, the product development departments have continuous communication with the factories since the construction and the configuration of the engines has to be buildable and not disturb the flow in the manufacturing process. The activities that the product development departments are responsible of are included in the first (DVP) of the four core processes in Figure 12. The product development departments work with continuous projects on new innovative designs to lower costs, enhance quality, pursue sustainability and keep up with the competition, while communicating with the production to assure that the product is not too complicated to construct and that the existing tools are suitable for the eventual new components, otherwise, new tools and equipment could be needed. The product development team sends design change notices (DCN) to all concerned parties when the design for an engine is altered. A DCN is a document presenting a modification in an engine's design, in form of new articles, new material or a different structure of components. There are three different types of DCNs, DCN with new modules, phase out modules (where a module is removed) and DCN where an existing module is replaced by a new one. The DCNs are organized by sending out two sorts of documents: D-DCN and K-DCN. A D-DCN is the document containing information about the design alterations or new articles in the engine. This includes the drawings and 3D models of the engines and the including articles.
A K-DCN shows where in the engine structure to place the new article, in which engine and which factory.

When new legislations are introduced, such as Stage V, the product development team needs to re-design the engines with new components which also result in DCNs. Other reasons behind DCNs could be that the production has detected a flaw in the quality of the material or that they report that it is difficult or non-ergonomic to build. The purchasing department work on finding good deals with suppliers and try to optimize the choice of suppliers in terms of cost, quality, delivery etc. This means that if a similar or identical alternative for a component is found, it can result in a DCN. If the product development team considers the suggested new part as identical to the existing part, the article number does not need to be altered, and a DCN does not need to be sent out in the Kola system, which is viewed by the Back Office among others. The product development department work on new designs continually and the result of some projects are new DCNs, which can take approximately 18 weeks to be finished and ready for production.

Since Stage V came into force in 2019, engines produced during 2019 had to be adapted to the new emission standard. The research and development behind the Stage V engines was not finished in 2018, which motivated Volvo Penta to start a project called "The Bridge Plan". The Bridge Plan involved producing 5000 extra engines during 2018, to have engines to sell the next year before the Stage V engines were completed. Estimations and forecasts were done to plan the quantity of each engine type to be produced. The high pressure on the production facilities, mostly Powertrain Vénissieux, is one of the reasons behind delayed engines during 2018. The following subchapters describe the departments and processes related to the OTD process, to give an understanding for how the different parts of the business affect each other although the functions are explicitly separated in different departments.

4.1.2 Purchasing

The purchasing department at Volvo Penta receives the structure and the components of the engines from product development and sets long term plans for the components based on that information. Stage V engines involve new parts which in some cases require new suppliers, and it is the purchasing department's task to make business agreements with the suppliers. The engine blocks, components etc. are bought from different suppliers, which are chosen by the purchasing department, according to different criteria such as price, quality, delivery precision among others. Since Stage V requires a number of new components, the purchasing department needs to seek suppliers with good quality that match the requirements.

They also forecast the need of components several years ahead with continual updates to specify the required quantity, with the support of the order forecasts made by the Back Office. These decisions and selection of suppliers are made after the product development process and before the customer order process. In case of design change notices, the purchasing department cannot begin their work until the factories have inspected the DCNs and prepared the manufacturing for it. Therefore, a potential bottleneck is, according to their experience, the waiting time between sending the DCN to the factory and the inspection of it and preparation internally at the factory. Another possible issue is that when a design is changed, and the components also need to be substituted, the contracts between Volvo Penta and the suppliers need to be altered since the ordered quantity does not match anymore. This leads to renegotiation with the suppliers and eventually higher prices since the forecasted numbers has to be modified, which lead to shorter and more expensive contracts.

The activities of the purchasing department at Volvo Penta affect the performance of the OTD process mostly indirectly since they only determine which suppliers that will supply material to the D11 and D13 engines. Since they are manufactured by Volvo Powertrain in Vénissieux and Skövde, each factory has its own procurement department determining the quantity and frequency of material deliveries. The production facilities' own purchasing departments are described under the corresponding subchapters (4.2. Skövde and the D13 Engines, and 4.3. Vénissieux and the D11 Engines).

4.1.3 Front Office

The majority of the administrative activities connected to the orders, flow through the front office at Volvo Penta at some point. The order flows for engines D11 and D13 are identical at Volvo Penta and differ only when they arrive to the factories. They are responsible for entering the orders in the JD Edwards Enterprise (E1) system, setting the requested date according to the customer's preferences and verifying the orders. The front office has frequent contact with the customers and internally with sales and logistics functions. In case of difficulties to provide delivery at the requested date, the Front Office passes on the case to the Back Office with supply chain functions and contact with the factories. The Back Office plans the order to find the best possible date for delivery depending on the available resources and capacity of the factory and transportation of the goods. The Front Office then gets back the responsibility of the order and makes agreements with the customers. These steps are explained further in each section in this chapter.

The responsibility of investigating customer credits and releasing sales orders in credit hold belongs to the Credit Control department, but jointly with the Front Office, since different priorities, deliveries and other aspects also needs to be considered. The order flow through the Front Office is described in this subchapter, according to Figure 13., that illustrates the order of the activities with purple color for Front Office responsibilities. The activities shown in Figure 13. are explained in following subchapters.

As Figure 13. shows, the value chain starts with a customer purchase order, which goes through automatic technical validation and a credit validation, followed up with a planning of order (Back Office), in case the Front Office is not able to promise a delivery on the requested date. The order then goes back to the Front Office, that confirms the order and sends an order acknowledgment to the customer when the deal is sealed.

Figure 13. Order flow – Front Office perspective (purple/dark arrows)

4.1.3.1 Create Order

This step is the first step in the Value Stream Map over both engines (D11 and D13). The OTD process is in this case considered to start when the customer purchase order arrives to Volvo Penta, regardless of a system or contact person that supports the process.

When the design process is accomplished, tested and approved, eventually the customers can start ordering their customized engine starting from the start of order date set by Volvo Penta adjusted to the start of production date. The dates indicate when a new engine design is ready for manufacturing and customers can start ordering. The Front Office is responsible for placing the order into the IT-system JD Edwards Enterprise 1 (E1), where forecasts and production planning also can be reviewed. When the order is placed in the system, a chain of activities is initiated and can be followed via different statuses of the order. The status of the order indicates who is responsible for it and how long it has proceeded in the process. The order can jump back to a previous status if it needs to be rescheduled, i.e. it always reflects the current situation of the order. Statuses support all divisions at Volvo Penta in connecting different performance measures to the specific order since the statuses reach across the delivery date and invoicing of the order. This means that the lead time and the number of confirmed and firmed orders can easily be calculated by following the status of the orders. The order status is numeral and can be followed in the E1 system.

Customers can either enter their order directly into the Volvo Penta ordering system, ProSales, or contact the front office where they can receive help placing an order. A number of features are presented to the customers and they choose alternatives depending on in which country the customer is located (since the legislations differentiate), what vehicle or machine the engine will be installed in etc. Usually, the customer places the order in ProSales since the engines have several different configurations, that need to be selected manually. The order can also be configured with salespersons working for Volvo Penta, but in different regions, depending on where the customer is located. The salespersons have meetings with the customers to enquire about their preferences and present what Volvo Penta has to offer. Application engineers support the salespersons in these activities to configure the order correctly and the salespersons report the specifications to the Front Office, with information about quantity of engines, important dates, configurations etc. These teams are usually based in the corresponding regions and belong to the market units located in for instance Italy for Italian customers, America for customers from the USA and so on. The market units have their own teams with Front Offices, application engineers and salespersons.

The process of creating the order involves converting the customer purchase order into a sales order and can be repeated if big changes are made in the order that have led to order cancellation. When they want to order an ASE (authorized stock engine), which means that they are the most commonly ordered engines and thus have a safety stock in the warehouse, the order can be placed by making a call to the Front Office. Since these standard engines tend to have a level of safety stock at the warehouse, the lead time for the OTD process is much shorter compared to an engine with a unique configuration. It takes a couple of minutes for the order to go through all the electronic processes including validation and confirmation of the order, excluding the manufacturing step, given that the customer passes the credit check. Since it already is assembled and stored at the hub (distribution center), the lead time depends only on the final destination and the geographical location of the customer. In this case, almost the entire OTD lead time is for the transportation from the hub to customer, which is the final step in the value chain, and will be specified further on in the following subchapters.

When the order is unique, i.e. not an ASE, the OTD process naturally becomes longer and more complex. The order goes through the same initial steps where credit checks and other types of validations are performed. In this case, the engine needs to be planned and produced, which requires several additional steps. Subchapter 4.1.3.3. explains the purpose of the process “plan order”.

Important to point out, is that one order does not always correspond to one engine. The approximate number of engines per order is 2.2. The orders usually contain 1-10 engines. Since the yearly demands (2018) for the D11 and D13 engines are 2215 and 5651 respectively, the takt time per D11 engine is 50 min and for D13 it is 19.6 min. The takt time is calculated based on the demand of year 2018 with 231 working days and one 8-hour shift per day, at the Volvo Penta office. The takt time for the factories might differ from these numbers due to several working shifts and lesser working days in the Vénissieux factory. Due to the average of 2.2 engines per order, the takt time for Volvo Penta should be lower. Counting on number of orders instead of number of engines, the number of orders should be approximately 1007 for D11 and 2569 for D13. The takt time is therefore 110 min and 43 min for each engine respectively.

When asked for the percentage of complete and accurate, the average is estimated to be between 60-70%, at the order creation step. This means that the Front Office cannot enter the order directly in around 40% of the of the cases. This is believed to be caused by changes in the regulations in the business (legal framework) or production rules (e.g. combination of different components), that people are not aware of or because of unawareness of when they come into force. When these kinds of errors that delay the work of the Front Office occur, hold codes appear in the system, showing either a technical hold code, that can be legally binding or a business hold code, which mostly consist of recommendations. The technical hold codes could also result from orders that are illegal to sell to certain countries due to regulations etc.

The process time for this process is relatively short (5 min) and the estimated lead time of 10 minutes includes system delays and any corrections and rework.

Table 3. Performance of the order creation process

Process Time	Lead Time	%C&A	Takt Time D11	Takt Time D13
5 min	10 min	70 %	110 min	43 min

4.1.3.2 Validate Order

This step comes after the step "Plan Order" (Back Office), but only if the order required order planning caused by capacity or resource shortages. If the order can be delivered at the requested date, the order skips the "Plan Order" step, and goes straight to the "Validate Order" step (Front Office).

Before the Front Office handles the orders, the customer purchase order has gone through automatic validation to check if the combination of features is feasible or if the customer has acceptable creditworthiness. If the customer has selected an oil pump that is not compatible with a certain configuration or base engine, a hold code is created automatically in the validation step, stating that there is some error in the order. Other reasons behind hold codes could be that in case of orders registered before new DCNs, the orders could no longer be valid if the DCN is compulsory and is applied within a short period of time. This could be due to quality problems and other urgent matters. The hold code appears in the order handling system E1. Validation of the order is done repeatedly and automatically, and is, other than the technical part, also a credit validation of the customer. The technical validation of the order occurs frequently throughout the process and in connection with status updates, until the order is firm. The reason why the technical validation is repeated during the process is because different regulations and DCNs can come into effect before the order is firmed and passed on to the factory. The order entry system (Prosales) for customers controls the eligible options to avoid unfeasible combinations, but due to a large number of regulations and changes that vary from day to day, the system can have some loopholes. When the validation is passed, the order is confirmed by the front office which sends an order promise to the customer.

If the credit validation of the customer does not pass automatically, the customer credit is assessed in this step. The credit check is made manually by the credit controllers if it does not go through automatically without any hold codes, and the process varies broadly depending on the origin of the customer. If the problems are caused by invoices that bind capital, the hold code can be overruled if the Credit Controllers know that the money is incoming. In case of a low creditworthiness, a deposit must be paid to Volvo Penta, before the confirmation, manufacturing and delivery of the order. When the customer requests an authorized stock engine (ASE), the credit limits are less strict, due to the possibility to resell the engine in case of an inability to pay. However, many orders are adapted to the specific customer, and to avoid big economic losses due to bad credits, the payment is always secured in some way. A customer with low creditworthiness, in some cases, needs to issue a letter of credit, which is sort of a bank loan that is brought out in favor of Volvo Penta. It is then sent to a Swedish bank, that receives a document that they will approve if it is correct. The Swedish bank will further send information to the financial functions at Volvo Penta, that can proceed with the order planning.

The letter of credit that is issued by the customer at their local bank needs to contain information regarding the validity time of the letter of credit, a description of goods and the latest shipping date.

When the engine is produced and is ready for shipping, a bill of lading is sent to the Swedish bank together with other documents containing all required information about the purchase. The information is forwarded to the customer’s bank which then allows the customer to collect the parcel.

For international customers, the credit check most often works as described above. It is very unusual for the orders to go through the processes automatically without any manual assistance. A letter of credit can maximally be valid for 240 days, which allows the customer to pay the order within that period of time. Considering the time value of money, which means that an amount of money is worth more the more time has went on (possibility to invest), Volvo Penta needs to compensate for that sum if they want to get the payment sooner, and transfer the amount to the international bank. The compensation depends on the size of the loan and is calculated by discounting the sum 240 days back. The reason why it is preferable to receive a payment as soon as possible is the possibility to shorten the days payable outstanding ratio (average time to get paid), which in turn is favorable due to eventual investment plans etc.

The validating of an order takes approximately 5 minutes if no bigger issues arise, but as the process can be complex, especially with international customers, an average lead time for this step does not say much due to the high variations. The process can include long lead times related to waiting for approvals and contact with different parties.

Table 4. Performance of the order validation process

Process Time	**Lead Time**	**%C&A**
5 min	1-5 h	100 %

4.1.3.3 Confirm Order

In this step, the order is confirmed to the customer and an order acknowledgement is sent if there can be a match for the requested date. If the possible delivery date differs with 1-2 days from the requested date, the order can still be confirmed due to a small difference. If the engine cannot be produced and delivered until several days after the requested date, the order is sent to the Back Office for the step “plan order” after it has been validated in the previous step. This step is automatic, if the orders do not need any further planning, which would make it manual, involving customer contact.

The process time for this step is approximately 2 minutes, but the lead time can differ much depending on waiting times in the communication between the Front Office and the customer.

4.1.3.4 Invoicing

The invoicing of the orders is done by the Front Office after the order is delivered. This process is triggered by the receival of a “Shipment Confirmed” status that the Delivery Handler in the Back Office confirms. This step is not included in the OTD process in this case but it is the last step that completes the order cycle. Invoicing takes approximately 2 hours to complete with matching process time and lead time, since the work can be done uninterrupted.

4.1.4 Back Office

A Back Office is usually known as the part of the company that does the work behind the scenes while the Front Office is the face of the company. In this case, only the supply chain and logistics functions of Volvo Penta are presented since they affect the value chain in the order to delivery process directly. The supply chain department at Volvo Penta work with resource and transport planning, including forecasting of orders and contact with the factories that produce the engines.

As shown in Figure 14., the colored (purple) arrows stand for Back Office activities. The order planning is done by the Supply Chain Coordinator at the Volvo Penta Back Office, in the event of mismatches between the requested date (by customer) and the possible delivery date. The new date is then discussed with the customer and confirmed (by the Front Office) if accepted, which the Back Office then can “firm”, meaning that the order is ready for production.

Figure 14. Order flow – Back Office perspective (purple/dark arrows)

4.1.4.1 Plan Order

The planning of the order involves providing the customer with a delivery date, according to the availability of resources, transport possibilities with holidays and desired mode of transport in mind etc. When placing an order, the customer informs Volvo Penta about the requested delivery date (the date the customer wants to receive the order), which is confirmed or cancelled by the Supply Chain Coordinators depending on the outcome of the planning process. Issues that may occur that prevent a smooth flow in this process are, for instance, an imbalance in the available quantity of components that are required for the engine. This means that some components or kits (complementary assembly parts sent separately with the engine to the customer) are missing, and the supply chain planner needs to solve the problem by investigating alternative possibilities to not divert too much from the requested delivery date. The best case scenario needs to be found to avoid inconveniences for the customer, and deliver the engines as soon as possible.

In some cases, a customer orders, for instance, 5 engines, whereof 3 of them can be delivered on the requested date and the 2 others will be late. It is the SCCs job to plan the orders so that they are finished at the same time, since they always are transported together, due to environmental and economic reasons. The supply chain division then does a re-promise of the order and postpone the requested date.

The targeted lead time for “create order” and “plan order” is under 48 hours and the orders do not always flow according to a FIFO (First in, first out) approach, since the order planning inboxes tend to be full and the supply chain coordinator needs to prioritize the orders according to requested dates, therefore, the lead time for this activity fluctuate greatly. The lead time is also affected by the need of contact with other parties, such as the factories. The order planning is repeated until the customer is satisfied with the delivery date or the order is cancelled. In some cases, the engines are urgent due to different reasons for the customer, which Volvo Penta can solve by “borrowing” engines from different customers, meaning that an order meant to be delivered to customer A can be delivered to customer B according to priorities and agreements.

The responsibility areas for the Supply Chain Coordinators (SCC), that are responsible for this step, are divided by different factories. The SCC that is responsible for the D13 engine also plans orders for other engines produced by Volvo Powertrain in Skövde. The same goes with the D11 engine that is planned by a SCC in charge of the Vénissieux factory. The two engines each have one corresponding SCC and given the quantity of ordered D13 engines and the full order planning inboxes, the work load distribution should be looked into.

The approval and rejection of returns also belong to the Back Office’s and the SCCs responsibility areas. The SCC checks that all the forms are filled in correctly and approves the returns. The final approval is done by the Front Office and credit notes are issued in E1 and emailed to the customers.

This step involves planning of between 4-40 orders per day, with a large variation from day to day. An estimation is that the SCC plans approximately 15 orders per day. The lead time of maximum 48 hours is set by the back office as a guideline. That means that the orders planning needs to be planned within 48 hours. The lead time can be this long in the cases where contact with the factories are included. Another time consuming issue is that the SCC needs to contact the front office first in order to reach to the customer to confirm that the new date is approved. The process itself takes approximately 10 minutes.

Table 5. Performance of the order planning process

Process Time	Lead Time	%C&A	KPI
10 min	48 h (max)	60 %	Number of engines sent to the next status within 48h: ~95%

4.1.4.2 Firm Order

“Firm Order” is a status resulted by the process of firming the order. An example of a status is 600, which means that the order is firm and cannot be changed by the Front Office. Status 560 on the other hand indicates that the order is confirmed by Volvo Penta but not *firmed*. In this case, the Back Office can communicate with the Front Office to check if the order is allowed to be firmed before the latest date, which is the release date. The purpose of firming the order before deadline is to generate a demand to the factory, so that the Order Office and the Procurement department at the factories can start their work earlier, which increase the chances of reassuring the right amount of resources for the orders when they are needed.

Firm order is one of several statuses that the order goes through. What distinguishes this status from the others, is that firm order is the point where the order is released from Volvo Penta and is ready for production. After this point, no changes are allowed, and firm orders are included in the forecasts as definite orders. The forecasts also contain a number of preliminary orders, which still can be altered in terms of quantity etc. This status is meant to initiate the physical transformation of the product (production), and includes ordering the software, start of work order and creation of chassis ID.

After the preliminary order is firmed, a freezing period is initiated, which means that under this period of time, the order cannot be cancelled and should not be altered either (although it happens) since the factories start planning and producing the products. The freezing period is 15 days for Skövde and 18 days for Vénissieux, which also are the minimal lead times presented to the customer after the order is firmed. The firmed orders are included in the files that are sent through the system CPO (Central Planning Office) every evening.

The firming of an order is a simple operation in CPO which makes the process time 2 minutes, in case it is done manually. This step is done manually when the Back Office wants to firm the order before the freezing period starts, otherwise, it is firmed automatically at starting day of the freezing period. Firming the order manually involves communication between the Back Office and the Front Office, leading to the lead time of approximately 1 hour per order.

Table 6. Performance of the order firming process

Process Time	Lead Time
2 min	1 h

4.1.5 Forecasting at Volvo Penta

The Supply Chain Planners at Volvo Penta create forecasts for engines, that, as mentioned before, contain of forecasted, preliminary and firmed orders for a rolling 12-month period. The approximate distribution between the order types is illustrated in Figure 16., for both Skövde and Vénissieux. They make 12-month order boards that are entered in the order books sent to the factories via E1 to CPO. The forecasted orders are updated every period, which occurs each month and are referred to as, for instance, P04 for the month of April. Each period, a 12-month plan is created whereof the first month consist of firm orders, the two following months of preliminary and the remaining part of the orderbook is forecasts. The Forecasting involve predicting the demand based on historical and recent existing information, and the growth of sales for each period. An average distribution for the orders sent to Vénissieux is 81% forecast, 9% firm and 11% preliminary orders. However, these numbers fluctuate depending on the season, engine type and several other factors. For instance, the period before summer can bring a higher volume of firm orders due to customers needing their engines before the summer vacation when the whole factory is closed for a month. This means that the order book with firm and preliminary orders reaches further away. The circumstances affect the orders considerably and could also arise from launching of new engines, temporary long lead times which lead to higher number of orders, etc.

In this study, only the value chains for industrial diesel engines, D11 and D13, are analyzed. The forecasting of industrial engines involves probably less uncertain predictions, compared to engines for versatile marine use, where the demand depends more on trends, the global economy etc. All the D11 industrial engines are versatile engines, and the D13 industrial comes can be both versatile engines and genset (power generation engine).

Currently, there can appear issues with the connection between E1 (where the orders are initially entered by the Front Office) and the order book, which leads to missing information in the order book.

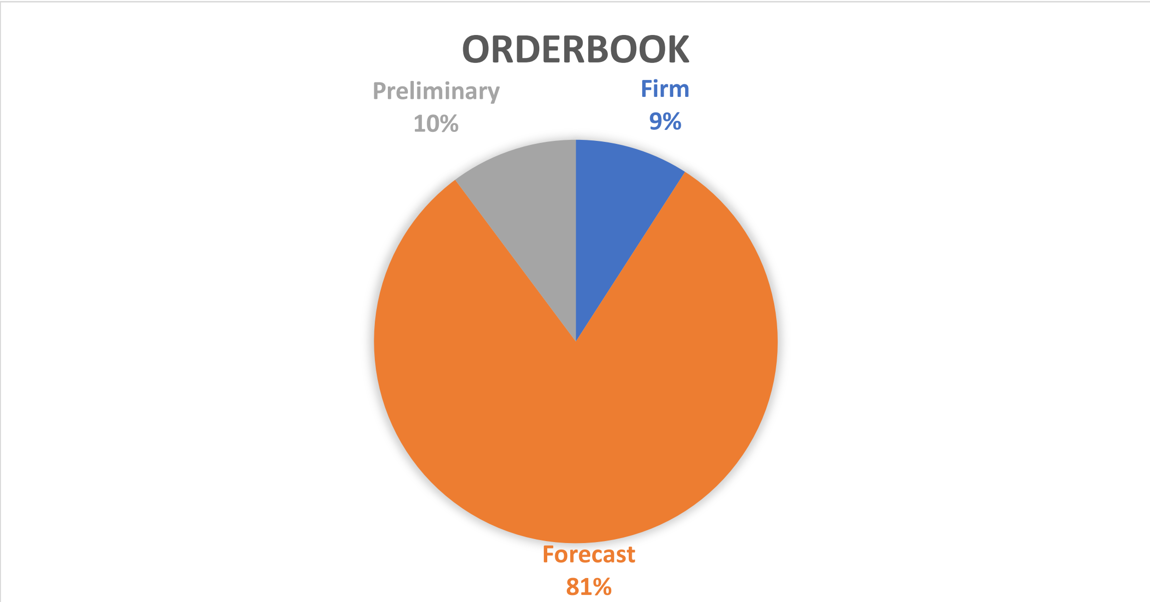

Figure 15. The distribution of the orders sent to Powertrain

4.1.6 Performance at Volvo Penta

The performance is measured in different ways at Volvo Penta and each function often has its own measurements and indicators to review their work both in long term and short term. The usual performance measures are presented below with brief explanations.

- *Delivery Precision* – Ratio of number of units delivered on time divided by the total number of dispatched units, presented in percent (%) and quantity. Measured in two steps, whereof the first step assesses if the production is on time, and the second step shows how much the warehouse at the production facility ships out on time.
    - Unit of measurement: Percent (%), Quantity
    - *Follow up frequency*: rolling 6 months, year, month, week
    - *Measured by*: Regions, Branch plats, Market areas, Customers
    - Target: N/A
    - Actual: N/A

- *Service level* – Measured against customer request, however if the requested lead time is shorter than the target lead time, the service level is instead measured against the target lead time. The lead time is measured from order entry in E1 to the allocation date at the last branch plant in the supply chain and includes order management lead time at both Front Office and Back office, production lead time and transport to last branch plant. It does not include transport lead time to the customer. The difference between service level and delivery precision is that the service level shows how well Volvo Penta can adhere to its target lead times, while delivery precision indicates disturbances for confirmed orders. A low service level will indicate prolonged lead times, whereas a low delivery precision will indicate disturbances and delays (Volvo Penta, Service Level Monthly Report 2019-04-01). See Table 7. and Table 8. for the actual service levels for the two engine families (D11 and D13) divided in three time periods and in three different geographical segments.
    - Unit of measurement: Percent (%)
    - Target Service Level: 85%
    - Target lead times:
        - 6 weeks – industrial D5-D16 Power generation engines (2 weeks for ASE engines), includes D13 industrial, power generation engine
        - 7 weeks – industrial D5-D16 Versatile, includes D11 and D13 industrial versatile
    - *Actual:* (see Table 7. and Table 8.)

Table 7. Service level for each engine divided in three periods

Service Level	**Target**	**Actual (01/2019)**	**Actual (02/2019)**	**Actual (03/2019)**
D11	85%	50%	70%	85%
D13	85%	78%	76%	67%

Table 8. Service level for both engines divided in segments

Service Level	**Americas**	**Europe**	**International**
D11 & D13	37%	75%	58%

- *Order Fill Rate* – Measured by dividing the number of orders in the order book (shipped orders) with the demand plan (forecasts). It is an indicator of the risk in the supply chain and the aim is to have a high fill rate in order to prevent delays for production of a product.
    - Unit of measurement: Percent (%)
    - *Target*: Period 1: 85%, Period 2: 50%, Period 3: 25% (The periods start from the period the order book is sent, the closer the time period, the more accurate the forecasts should be)
    - *Actual*: N/A

- *Forecast Accuracy* – How well the demand is predicted.
    - Unit of measurement: Percent (%), Quantity
    - Target: N/A
    - Actual: N/A

4.2 Skövde and the D13 Engines

When the orders arrive to the Skövde factory, the Order Office at the factory handles the orders and plans the distribution of resources and capacity allocation for production. The task is thereafter handed on to the Procurement department at the factory, that is in charge of ordering the right quantity of material from the suppliers that are chosen by the Purchasing department at Volvo Penta. When the order is ready for production, the production receives information about what engines and when to produce them, based on a production plan. The finished engine is then packaged and labelled and prepared for delivery. The processes that take place in Skövde can be followed in Figure 16, highlighted with a darker (purple) color.

Figure 16. Order flow through Volvo Powertrain in Skövde

4.2.1 Order Handling – Order Office Skövde

Front office at Penta sends a file every night to Skövde, with forecast, preliminary and firm orders. The orders are always sent with a 12-month plan for the forecasted orders. The files are sent through a system named CPO (Central Planning Office), every evening. CPO is like a transmitter receiving information from Volvo Penta and distributing it to the Skövde and Vénissieux factories, among others. The orders sent through CPO are forecasted, preliminary and firm orders, which means that the preliminary orders can be changed or cancelled when they approach the intended firming day. The preliminary orders consist of orders with a distant delivery day, which means that they will become firm 15 days before requested date, if not firmed earlier by the Back Office at Volvo Penta. At the Order Office in Skövde, one person is dedicated to the tasks connected to Volvo Penta.

When CPO is distributing orders and sending information to different systems during the daily runs that take approximately 4 hours every evening, the balance of volumes and delivery plans are frozen. The demands are sent to the production and material planning systems that triggers alarms in the system if it detects deficient capacity or resources in the production and material. The alarms have different levels of priorities stating if it merely is a warning or a blockage in the system.

CPO sends information to KKL, which is a production planning system that contains information about the order content and the technical structure of the engines. The DCNs that show the BOM (Bill of Materials) for the engines, are visible in the KKL system. A BOM is a list of articles included in the engines that specifies all components, quantity and article numbers. When the Order Office has planned the capacity, the information is automatically forwarded to SHIP, which also is a production planning system for the orders, scheming the lead times for the specific engines based on past lead times. The purpose of this scheming is to optimize the production so that the engine will be finished at a certain date, to avoid delays and excess inventory.

The planning at the Order Office also involves simulating a situation in a system, to see if they are able to match the orders with the supplier deliveries and other factors. This is done if an enquiry that requires change of the initial plans from Penta is sent. In this case the data systems send information downstream from the procurement systems to MMS (the black box) and then back to SHIP (production planning, lead times) and to CPO (order transmitter).

The Order Office then passes on the reviewed and planned orders to Procurement for material planning.

4.2.2 Supply Material – Procurement Skövde

When the order handling at the Skövde factory is finished, the work is received by the Procurement department. The employees at the Procurement department are responsible for their assigned suppliers, but do not work with specific companies, like the Order Office that has a person for Volvo Penta orders. They are responsible of sending long and short term plans to the suppliers, to reassure appropriate levels of material. The Procurement department receives information from a system named MMS (Material Management System) that presents the needs of material based on orders in the CPO system. MMS is regarded as a black box containing all information about the orders, since all transactions are meant to pass through MMS.

These two systems receive the structure of the engines and information about which modules they are built of from a Product Preparation system, PAM, which means that the Procurement department does not read the number of whole engines, but the quantities of different components. The structure is built with different modules by the Product Development at Volvo Penta. Modules in the engine contain the articles that the modules are made of, where the specific articles are not visible for the assembler at the production. An alternative for modules is variance, that allows the reader to see a detailed list with a structure of the engine. Variance does not divide the engine in different modules but consists of an entire string of articles as a more easily read list. PAM is a system that contains information about the engines' articles, weight, costs, the starting date for DCNs, etc. In order to distinguish witch articles are needed, the Procurement department needs to decompose the modules of the engines to see which articles they contain, which is somewhat more time consuming compared to interpreting the engine structure with variances. The system is updated when an engine structure is altered, i.e. when a DCN has been sent from the Product Development at Volvo Penta. The information in the PAM system needs to be prepared before CPO starts sending orders. If an engine design is altered in some way, it has to be visible in PAM in order to start ordering that specific type. A mismatch between PAM and CPO stops the flow and needs to be solved by the Order Office. This can be due to kits (complementary assembly parts sent separately with the engine to the customer) that contain expired articles. When the kits are a part of a firm order, the orders require manual procedures to solve the problems.

Thereafter, a procurement system, Pipechain, that is connected to supply chain functions, receives information via EDI (Electronic Data Exchange), that is automatically sent to the suppliers, so that they can start planning the deliveries of material to the Skövde factory. The

Procurement Department is mainly involved with the system Pipechain and they are notified by the suppliers about the deliveries and communicates simultaneously with the goods reception to make sure all parts are working.

The Procurement department did not experience unusual workload coming from Volvo Penta engines. However, the kits that are complementary assembly parts can disturb the flow from the Order Office and Procurement point of view. The reason is that they are included in the forecasts, and when the preliminary orders for kits are meant to get to the firm status, they are in some cases cancelled. This can happen as soon as one week before start of production date, and the material is either already been received or ordered from the suppliers. The material meant for kits now becomes part of the costly excess stock. The excess stock at Skövde Powertrain contains a large amount of Volvo Penta articles compared to other engine developers, due to inconsistencies in the orders.

The articles in the Volvo Penta engines are often more difficult compared to other clients, since they can be bigger or more complex. The longer lead times resulting from the complexity lead to longer freezing periods with the suppliers due to the longer production time and the need to assure the orders. The long freezing periods with suppliers can also be due to smaller volumes at Volvo Penta, compared to other engine developers that have high volumes and can make different kinds of advantageous arrangements with the suppliers.

The deliveries from the suppliers are sent to Skövde Powertrain with transporters chosen by Volvo Production Logistics (PL). The transport service is purchased from PL, that is a part of the Volvo Group, with the purpose of making the transports more efficient. They optimize the transports by shipping items from different parts of the Volvo Group together.

An advantage for Skövde Powertrain is that a big fraction of the material and the engine blocks is obtained from Volvo's own foundry ("gjuteri" in Swedish) in connection with the production site. The deliveries can therefore be adjusted according to the inventory and it takes approximately 15 minutes for the supplies to arrive.

4.2.3 Produce Product

The production of the industrial D13 engine is explained briefly in this subchapter since it has a high impact on the value chain of the product. This is where the actual physical transformation of the product is done and therefore prepared for delivery to the hub (distribution channel) which is a stopover before shipping to final destination.

Skövde Powertrain manufactures engines for different clients, meaning that the product variance is high, and the focus is not on the Volvo Penta engines and their flow. The industrial Volvo Penta D13 engines are a part (~ 5%) of a bigger flow with numerous other engines, with a FIFO (First in first out) principle throughout the majority of the processes.

The employees work in two shifts of 8 hours from Monday to Friday approximately 231 days a year. The system production system GASS (Global Assebly Steering System) steers the production from start of components to delivery of components, while MACS (Material Control System) holds information about where all material is in the factory.

The production is aiming to follow a pull oriented production system for replenishment of material with electronic Kanban systems, to maximize the value adding time. The production lead time for the D13 engine is 40.3 hours (~1.7 days) and the total lead time at the facility is 56.5 hours (~2.3 days). The total lead time includes the waiting time at the shipping out area of the facility.

4.2.4 Pick, Pack and Deliver Product

When the engine has gone through all production processes unmarked, it is picked, prepared and packaged at a packaging area prior to the shipping area. The packaging area consists of 5 different stations and 7 operators, and the experienced issues disturbing the work flow are mainly due to material shortage and deficient material for packaging.

When the engine has been packaged, it is placed in the shipping area outside of the building and is shipped off to the Volvo Penta hub (distribution center) in Vara (Sweden) the same day. At this point, the Front Office at Volvo Penta notices a status update showing that the engine is ready for transport booking. They inform the Delivery Handler at Volvo Penta (Back Office) about which engines need to be delivered and they will check the delivery terms that state which agent/transport company is going to be used for the transports. The Delivery Handler is responsible for booking transports according to the carriers that Volvo Production Logistics (PL) has arranged. The end customer always pays for the shipping, allowing them to either take the responsibility to arrange the shipment by themselves, or to let Volvo Penta arrange and bill them for it separately. If the customer takes the responsibility for shipping, the packages are considered to be in their possession when their transport company receives the order, which means that it should match the requested date (the date the customer wants to receive the order). The responsibility handover depends on the mode of transport, which could be marked as “FOB” (Free on Board), meaning that the order is shipped by boat and the customer and their insurances are responsible for the order when the order is on board.

This is when a dispatch note is sent to Volvo Penta and a Bill of Lading is sent with the packages declaring the engine number, weight, volume and number of packages. If the engine is sent with a kit, it would be 2 packages. The bill of lading is a valuable document and the owner of that document is the owner of the packages. It is also the basis for the invoices since the measurements of the packages and engine number need to be included.

Before the engines are shipped off to the end customers, they are always sent to the hub in Vara, Sweden, and the transports from Skövde Powertrain to the hub take 1.5-2 hours with the carrier “Olssons Åkeri”. The shipments to Vara go 4 times a day during office hours and the trucks are loaded with around 10 engines which leaves room for a few kits (complementary assembly parts).

Since the delivery precision is measured both by the number of engines that the production makes in time, and by the number of engines sent out from the shipment area in time, if the production time is extended for some reason, the engines still have time to catch up with the shipment day. This is due to a couple of safety days given to the engines in the warehouses, so that they do not get too delayed in case of any deviations.

4.2.5 Performance at Powertrain Skövde

Powertrain Skövde measures their performance for the whole factory with several different measures. Important to note is that the numbers presented below are not specific for Volvo Penta engines. The delivery precision for Volvo Penta differs from these numbers and is presented in Chapter 4.1.6. Measuring Performance at Volvo Penta.

- Lead time for production: 40.3 h (~1.7 days)

- Total lead time at Powertrain Skövde: 56.5 h (~2.3 days)

- Delivery precision (April 2018 – April 2019):

  - Actual: 645 ppm (99.94%)
  - Target: 300 ppm (99.97%)

- Quality - Number of engines with defects in relation to one million engines manufactured. Based on number of complaints on finished engines delivered from the factory (2018)

  - Actual: 649 ppm (99.93%)
  - Target: 750 ppm (99.92%)

- Inventory turnover rate: *N/A*

4.3 Vénissieux and the D11 Engines

The order flow at Powertrain Vénissieux is identical to the order flow at Powertrain Skövde, using the same data systems and the same division of order responsibilities into different departments, i.e. Order Office and Procurement before production. See Figure 17. for an illustration of the order flow.

Figure 17. Order flow through Volvo Powertrain in Vénissieux

4.3.1 Order Handling – Order Office Vénissieux

Similar to the Skövde factory, the facility in Vénissieux receives the orders in the same form and in the same system, CPO. The orders consist of forecasted, preliminary and firmed orders, but the distribution between the three types of orders differ somewhat from the numbers sent to the Skövde factory, see Chapter 4.1.5. Forecasting at Volvo Penta for information regarding the forecasting. The freezing period for firm orders is 18 days, three days longer compared to Skövde.

The %C&A (Complete & Accurate) is unknown, i.e. the amount of rework due to incorrect information received, but it happens that the orders can have the wrong configuration and contain different modules that does not go together.

4.3.2 Supply Material – Procurement Vénissieux

The Procurement department at Vénissieux does similar work to Skövde. They send the demands to the suppliers with Pipechain based on information acquired from MMS (Material Management System). What is different in Powertrain Vénissieux compared to Powertrain Skövde is that they do not have their own foundry that produces material and engine blocks, but they receive deliveries from Skövde 4-5 times per day with approximately 4 days of transportation time.

Powertrain Vénissieux consider working with variances as a way of reading the technical structure in the engine, more advantageous than modules. All their other customers work with variances and the system communicate better in those cases. The reason is according to the Order Office that the forecasting is more accurate when working with variances due to a function in CPO that allows that. Imprecision in the forecasting leads in turn to missing parts for the engine since the orders from the suppliers cannot be ordered in time.

Missing parts is the biggest issue when it comes to Volvo Penta engines and the delays that lower the delivery precision, and is explained in the performance assessment section, 4.3.5 Performance at Powertrain Vénissieux.

4.3.3 Produce Product

The Vénissieux factory layout is somewhat different than in Skövde, but with similar methods and systems steering the production. They use the same data systems and follow a pull-oriented production flow with a FIFO principle in most of the stations. The buffers are principally also FIFO, but also depending on the priority and urgency of finishing an engine.

Powertrain Vénissieux manufactures engines for several other customers and also other engines for Volvo Penta, other than D11 industrial, which make approximately 4% of all the engines.

The employees work in two shifts of 7 hours from Monday to Friday approximately 215 days a year. The production lead time for the D11 engine is 34.7 hours (~1.4 days) and the total lead time at the facility is 119.4 hours (~5 days). The total lead time includes the waiting time at the shipping out area of the facility.

During the field trip at Powertrain Vénissieux, it was also discovered that a remote oil filter included in the engines is a bottleneck that disturbs the flow on the assembly line, since it takes approximately 30 minutes to assemble outside the line. This step can lead to 2 extra days for the engine in production. It was a problem with the former emission regulation and will remain for Stage V engines.

The flow of work on the line is also disturbed by the current mix of engine orders sent to the production, which could be improved so that the flow will become smoother. The optimal mix would be an even distribution between complex/time consuming engines and simpler engines. To improve the interaction between Product Development from the different customers (Volvo Group Trucks Technology etc.) and Powertrain Vénissieux, “line walks” are performed so that each party can have their inputs to synchronize the design work with the production. This teamwork is however currently not implemented by Volvo Penta yet.

4.3.4 Pick, Pack and Deliver Product

After the engine has been packaged, it is transported with a forklift to an outside warehouse where the engines wait for shipping. The engines stop at a temporary buffer outside the production facility meant only for Volvo Penta engines, for 1-5 days and are transported to that location by a forklift driver also dedicated to Volvo Penta. The engines are stored in the temporary buffer until the kits are ready and the waiting time is in average two days for most of the engines, except for Volvo Penta engines, that often wait up to five days due to production problems or waiting time for kits. The placement of the engines in the final warehouse before shipment is based on the shipping days and they are prioritized accordingly.

The engines are shipped out from the warehouse 3-4 times per day with approximately 10 engines, kits and other loose equipment. In the warehouses, the turn over time is estimated to 1.5 days.

The hubs are placed in Krefeld, Germany and Genas, France, where the engines are placed for storage depending on their final destination. The engines going to customers located in Spain, Portugal, France, Italy, etc. go through the hub in Genas, and for customers in Central Europe, Nordic countries and the rest of Europe, the engines go to Krefeld. The lead time for transportation is around 1 day depending on which hub the transports are going to, since the hub in Genas is ~20 minutes away from Vénissieux.

4.3.5 Performance at Powertrain Vénissieux

Powertrain Vénissieux measures their performance for the whole factory with several different measures, similar to Powertrain Skövde. Once again, the numbers presented below are not specific for Volvo Penta engines. The delivery precision for Volvo Penta differs from these numbers and is presented in Chapter 4.1.6. Measuring Performance at Volvo Penta.

- Lead time for production: 34.7 h (~1.4 days)

- Total lead time at Powertrain Vénissieux: 119.4 h (~5 days)

- Production Delivery precision (2019):
  - Actual: 99%

- Quality – Number of engines with defects in relation to one million engines manufactured. Based on number of complaints on finished engines delivered from the factory (2018)

  - Actual: 2392 ppm (99.76%)
  - Target: 1500 ppm (99.85%)

- Inventory turnover rate: N/A

The delivery precision of Powertrain for Volvo Penta engines is lower than the overall delivery precision. Delayed engines seemed to be a problem for Volvo Penta engines at Powertrain Vénissieux. Out of 11854 engines sent to Volvo Penta, 1376 was late. This is 11.6% of the total number of engines, meaning that 88.4% of the engines were in time. The causes of delays are:

1. Missing parts/material
   (New parts/articles forecast not announced on time)

2. Disturbance in production
   (mainly hot test)

3. Change of needs from customers
   (quantity variations)

4. Delivery problems
   (waiting trucks blocking other trucks etc.)

The issue with the missing parts is caused by several different factors. The timing of DCNs is believed to be one of them, since the time set between receival of DCNs and start of ordering (for customers) often is too short, around 8 weeks. This means that the suppliers are producing the wrong parts, not the new parts/articles that the engines are supposed to include. Another factor could be the fact that Volvo Penta is their only customer sending their engine specifications in the form of different modules specifying the engine structure. This affects the forecast accuracy which also leads to risk of shortage of material. In the attempt to meet the market flexibility, Volvo Penta can according to Powertrain Vénissieux in some cases overlook the production constraints, meaning that the order process is not always respected in terms of times for the forecasted, preliminary and firm orders. When an order is firm, the order is supposed to be frozen and not altered. The tolerance for preliminary orders is higher, but volatile numbers for those engines also lead to imbalance in the production. From the production point of view, the flexibility for the preliminary orders is currently too high and a problem with the firmed orders is that they are firmed very late.

Modifications in a preliminary order does not give any notifications to the Powertrain plant, they appear only when a firm order is modified which leads to an alarm in the system, since changes in a firm order is not actually allowed.

Another factor affecting the missing parts issue that leads to delayed engines is that there currently is a problem with engines waiting for their kits in the shipment area. One of the reasons behind that imbalance could be that the kits are not included in the forecasts sent to Powertrain.

In the administrative processes at Powertrain Vénissieux, one person per department is dedicated only to Volvo Penta engines. The IT department develops specific tools only used for Volvo Penta which are linked to the way of ordering. It is apparent that they are allocating additional resources on Volvo Penta compared to other customers which understandably is costlier.

The problems behind all the delays can also originate from the Bridge Plan. As mentioned before, the Bridge Plan, which involved a production of 5000 additional engines to stock during 2018, caused a higher pressure on the production processes. The suddenly increased production volume had its effects on the production in form of irregular material demands, higher inventory buffers between the processes etc.

4.4 IT-systems

A large number of IT-systems is involved in the system and they communicate with other systems and divisions both manually and automatically. Most of the systems communicate with each other in both directions, but the flow is simplified to a few steps, according to Figure 18. and Figure 19.

In Figure 18., the systems connected to the orders in the administrative processes (Order Office and Procurement) are illustrated and explained briefly. The first point in the list below the name of the system indicates which division uses the system to read information and forward it to other systems and parties.

The main data systems used by the production facilities in Skövde and Vénissieux are identical, although each facility may have additional supporting systems that are not included in this value chain. This is because both facilities belong to Volvo Powertrain. Since Volvo Penta also is a part of the Volvo Group, the systems used by the office are compatible with some of the systems at the production facilities, which is beneficial to a continuous flow.

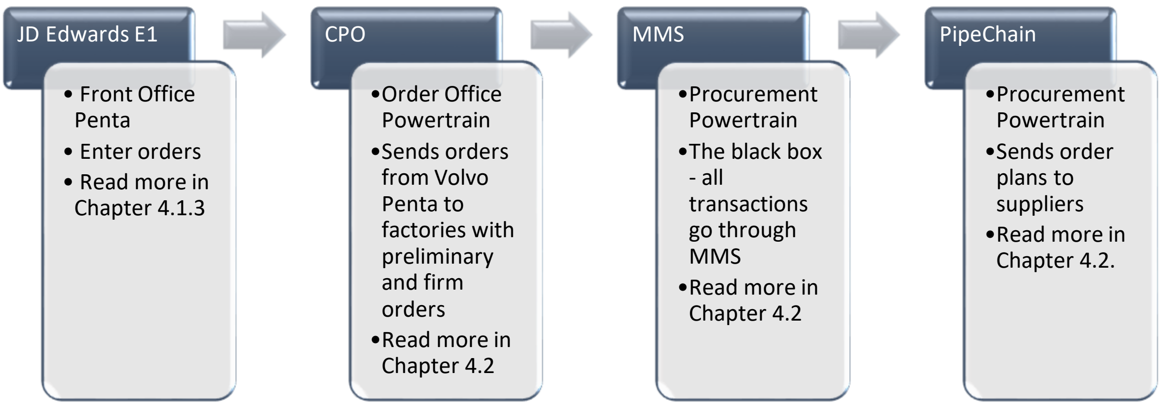

Figure 18. A selection of the IT-systems connected to the orders and the administrative processes

Figure 19. illustrates the information flow in the production and the main systems involved in the flow, although it does not show every single IT-system involved in the production.

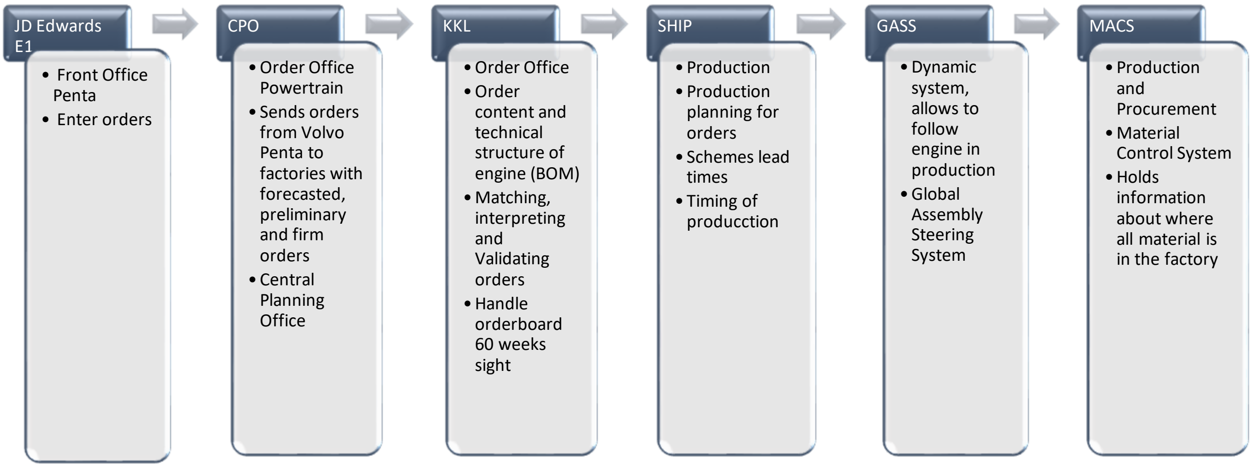

Figure 19. A selection of IT-systems connected to the production

4.5 Current State Map

The current state of the Volvo Penta processes from order to delivery are mapped according to the method of Value Stream Mapping. The map shows a macro view of the processes to form an understanding of the workflow and is in fact much more detailed in the reality, with several additional steps in all possible directions. Some of the steps are performed automatically, but a significant portion of the orders does not go through all of the processes completely automatically, and the current state map mainly reflects those types of orders. The Current State Map is shown in Figure 20., for a larger scale figure, see Appendix 1. The upper box, “HUB”, is the distribution center where the finished engines are delivered. The middle layer of the figure illustrates a selection of the IT-systems used in the order management and the production and the boxes in the bottom show the processes with data representing the performance of the processes. An estimated timeline is placed below the boxes, showing that the process time for the order administration is approximately 37 minutes and the lead time is around 51 minutes calculated with the estimations received from the interviews. However, the reality is quite different since the variation in the processes is very high, resulting in lead times fluctuating between one day and several months. This map should therefore be used as an overview of the processes, to form an understanding of the flow and to highlight where waiting times can occur. The lead times in the figure are measured from the start of the activity until the person responsible for it moves on to the next case. Due to the fact that the current state for the other engine family (D11 industrial) included in this study looks identical to the D13 engine family (except for production times), only the current state map for the D13 engine family is illustrated in a picture.

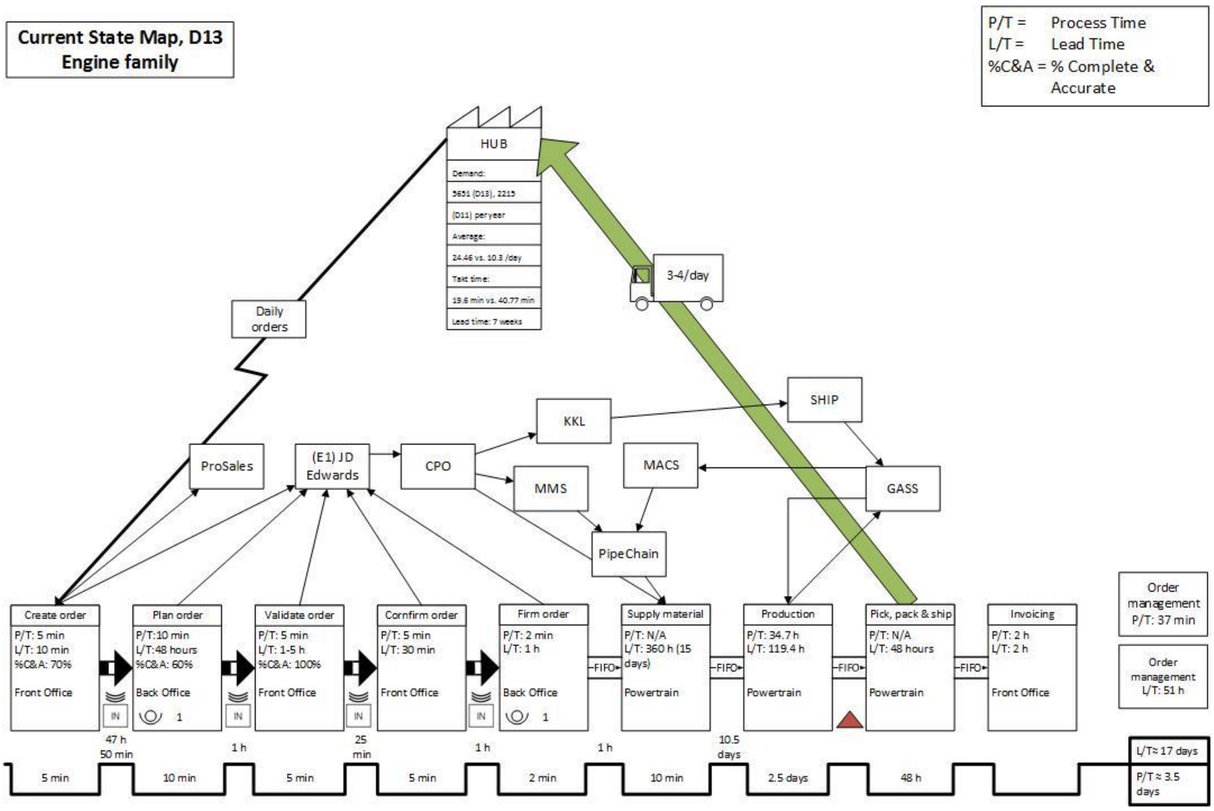

Figure 20. Current State Map

5 FUTURE STATE

In this chapter, the current state for the two engine families is analyzed based on the findings revealed while following the engines from order to delivery. The value chain is inspected starting from the Order Office at Volvo Penta in Gothenburg, Sweden, through both of the production facilities in Skövde, Sweden, and Vénissieux, France. The order to delivery process assessed in this study ends at the hubs, where the engines have a stopover before transported to the final destination. The wastes found within the processes are presented initially, followed by a consideration regarding the actual effect of the new emission standard, Stage V. A number of recommendations based on the analysis together form a suggested future state, to develop a better flow and improved interactions throughout the processes.

5.1 Wastes

Activities that lead to wastes were identified at the Volvo Penta office and in the connection with the Powertrain plants. The wastes are categorized according to the eight waste types defined in Table 2. in Chapter 3.4.2, and seen from an administrative point of view, instead of the production perspective where they usually are used.

1. Overproducing – "Producing more, sooner, or faster than is required by the next process" (Keyte & Locher, 2004). Since nearly all of the engines are built to order belonging to a specific customer, which means that the engines are not produced until the order is confirmed, the Front Office and Back Office handles the orders in a prioritized order to match the demand. However, the risk of overproducing can arise from planning an order before the credit validation is confirmed. Credit issues can lead to a delay or cancelling of an order, which means that the order that already has been planned by the Supply Chain Coordinator (SCC), can need replanning.

2. Inventory – Excessive physical inventory was not detected in connection with the administrative processes, nor at the warehouses where the components were stored.

   However, due to the introducing of new articles in connection with DCNs, the old articles still in use occupy space in the warehouses and should be aimed to be reduced. Inventory was seen at the production facility, with buffers between all workstations, although the production will not be specified further in this study.

   At the Volvo Penta office, filled inboxes were found at the order planning step, where the work load sometimes can be too high to resolve immediately when the work arrives. This prevents a continuous flow since the orders are queueing before this step.

3. Waiting - The most noticeable waste category at the Volvo Penta office is the waiting time within and between processes. Since the order responsibilities are divided between different departments and employees, the waiting for approval from others occurs frequently. One example of that is when an engine is ready for shipment, the Front Office notices the status update indicating that, and forwards the information to the Delivery Handler which books the transports, instead of the Front Office completing the task and contacting Volvo PL directly. Another example is that when firming an order, the SCC needs to contact the Front Office for an approval of changing the status to "firm order".

Waiting also stops the flow while waiting for information from customers. The Front Office maintains all the contact with customers and is also an intermediator between other functions at Volvo Penta and the customers. When Volvo Penta notices that an order cannot be delivered at the requested date, the customer needs to be contacted in order to find a better suiting date for both the production and the customer. This communication takes several detours with several parties involved in order to synchronize the customers' needs, flexibility and the production capacity. Waiting time in communication is also found between the Volvo Penta office and the order offices at the Powertrain facilities.

Waiting time was also found at the shipment area in connection to the production facilities, where the engines often were waiting for their kits, leading to delayed deliveries.

4. Extra Processing – Avoidable extra processing at the Volvo Penta office was not identified. Since it is common in office environments to make extra-detailed reports and having unnecessary steps in the workflow, extra processing may have been found if reports and meetings were investigated more closely.

5. Correction – This kind of waste involves all defects that occur in the workflow. Despite the automatic technical validation of the orders, it occurs that the configurations for the engines are infeasible due to incompatible articles. This could result from loopholes in the systems or incorrect DCNs sent to the factories. The need of corrections can appear already in the first step, which is the order creating step, where the customers may have chosen a setup that is not suitable for the geographical area or that they have combined articles belonging to different stages of emission standards. The same reason for errors can also be corrected after the order has arrived at Powertrain, meaning that the orders sent through CPO are incorrect. The reason why the errors can be detected so far in the value chain can sometimes be due to DCNs taking effect in the middle of the order processing steps.

6. Excess Motion – The staff was not observed closely during this study and any excess motion was therefore not detected. Excess motion includes excess movement from one department to another, difficulties in finding things, re-entering data etc.

7. Transportation – In an office environment, the waste of transportation applies to electronic information like excessive approvals, attachments etc. Since the responsibilities are divided into different areas, many of the decisions need approvals from other parties. Most of the parts at the Volvo Penta office have access to the same data systems and it can be questioned why the flexibility currently is not higher than it is.

8. Underutilized People – No explicit underutilization of people was discovered; however, the flexibility could be boosted by broadening the responsibility areas of everyone, making their daily work more overlapping, meaning that more people can take the initiative to do something outside their field of work. It involves developing the organization in collaboration with the employees.

5.2 Stage V Affecting Volvo Penta

The new emission regulation for the industrial engines, Stage V, affects Volvo Penta in several different aspects. The main consequence is increased product costs related to the design of the products making them more fuel-efficient and sustainable, but it has also brought some new costs emerging from the manufacturing of the engines.

Some of the existing articles included in the engine structures are replaced with new ones, making the purchasing departments reevaluating the current suppliers, and in some cases creating new relations and agreements. Stage V is not considered as a big change from the Front Office and Back Office point of view, since the order handling looks identical regardless of what the orders contain. However, seen from a probability and statistics perspective, the errors in the orders may increase due to a higher risk of unfeasible combinations and configurations, since the number of possible outcomes becomes higher. The total number of modules and articles will rise, and the variation and the number of different combinations will be even higher. Some of the existing articles will be phased out in connection with the launch of Stage V engines, but the total amount will probably become higher. These consequences will mainly affect the production of the engines due to new assembly approaches, which makes the lead time more volatile. What also affects the lead time, is the waiting time for the engines with delayed kits, postponing the shipment date from Powertrain Vénissieux due to that reason. The problem with the kits is an existing problem and is believed to remain even after the production of Stage V engines has begun.

During the field trips at the Powertrain facilities, the team leaders at the workstations were asked whether they think that Stage V will affect their work in some way; the majority did not anticipate any significant changes. Although it may be impossible to predict the effect of the new engines since the production of them had not started yet, the production should be adaptable for changes like Stage V because new DCNs are introduced frequently, which should not make the new engines a (too) big challenge to adjust to.

5.3 Future State Questions

The seven future state questions presented in Figure 21. and derived from the eight questions formed by Rother and Shook (1999), are answered in order to picture an improved future state.

Future State Questions

1. What does the customer really need?
2. How often will performance be checked?
3. Which steps create value and which generate waste?
4. How can work flow with fewer interruptions?
5. How will work be controlled between interruptions?
6. How will the workload and/or activities be balanced?
7. What process improvements will be necessary to achieve the future state?

Figure 21. Future state questions adapted to office (Keyte & Locher, 2004).

1. During 2018, there were 2215 orders for D11 which means a takt time of 50 minutes. For D13 the quantity was 5651 with a takt time of 19.6 min. The takt time indicates how often a customer wants an engine, and therefore how often the company should produce one, on average. To keep up with the customer demand, it is important for production to align with that pace. However, for the administrative processes, the takt time is lower since one order often corresponds to more than one engine. The average number of engines per order is 2.2 and the processes seem to keep up with the pace. The order planning step can be more time consuming than others which means that it could be divided between additional people. Also, the credit validation of the customers can become a long process in case of any issues, meaning that the takt time in that process can decrease.

2. The teams at the Volvo Penta office and also at the production facilities assess their performance on a regular basis. Except from meeting customer demand in means of takt time, the performance should be measured by assessing if other customer requirements are met. The Volvo Penta Office measures the delivery precision and the service level, which are significant factors for the customers, and the production measures delivery precision from their perspective and the quality of the products in terms of defects and complaints. The service level has however not reached the goal, which is 85%, although a significant improvement has been noticed during the first three periods of year 2019. In contrast with the delivery precision, the service level measures the number of orders that are delivered within the target lead time. Delivery precision measures number of orders that are delivered on or before promised delivery date, which can be outside the target lead time, thus the addition of the measurement of the service level, that completes the evaluation of delivery times. Every department has its own specific measures and the measures are not comparable with the other departments, which leads to suboptimizing of the organization.

3. The value creating steps are shown in the Value Stream Map, but by zooming into the processes and observing them in real life, a number of waste-generating steps can be found. This does not mean that the steps in questions are unnecessary, but that they are inefficient in some way leading to waste. The separating of the order responsibility at the Volvo Penta Office means that the tasks and the responsibilities are divided between different department and particular persons, which may be good in case there is a need to contact the person in charge to discuss an issue. It can also interrupt the flow if orders are accumulating at one of the processes, which could be avoided by letting the responsibilities become more flexible and allowing the organization to collaborate more internally.

4. As already mentioned, the order responsibilities can in some cases interrupt the flow and could become smoother by giving the permission to make decisions to more people. The step where the delivery is booked by the delivery handler could be made by the Front Office, since that is where the need to book a transport is initially detected. The responsibility does not need to be transferred to another department, but the possibility to book transports could be delegated to other functions when needed. The flow could therefore become smoother by forming multifunctional teams dedicated to the order to delivery processes of one product family, or some other constraint. Motivating the employees to study the entire flow instead of concentrating on their own tasks and how to suboptimize it to increase performance, would help them to see the value chain from the customer's perspective. By following the orders throughout the administrative processes, it was apparent that the interviewees were experts in their fields of work, but not many were certain of how the whole OTD process looks like.

5. In contrast to the manufacturing area, the different steps related to the orders are handled by departments that are often distant from each other. The work is not organized in the same way, as in a production line where almost all processes are visible and easy to follow. This makes it difficult for the staff at one process to see what is going on in the next and the previous step. The person responsible of the next step could be unavailable or have a full inbox, leading to queueing orders, which makes the system similar to a push-system, with people performing work without knowing if the next process is keeping up. This could be solved by implementing a FIFO principle for the administrative work. Since the customers change their orders frequently, a FIFO lane would make the organization more adaptive to the changes, because the effect of the changes will be smaller if the order has not gone longer than needed in the process. Limiting the work in process will improve the flow by decreasing the amount of queuing work.

6. The sixth question is about balancing the workload/activities and implies that imbalance at a process and a system level can lead to long lead times. At a process level, there can be some processes producing at a much higher pace compared to other processes. At a system level, there can be activities that are made monthly, which leads to unevenness in the workloads on both levels. By implementing FIFO lanes and cross-training staff, a stability can be achieved in the workplace.

   This leveling of work (Heijunka) should also be done with the production in mind, by considering the complexity of the orders and distributing them in an even way to bring more evenness the production. The team leaders at the production facilities requested some help from the order administration, to make the production more even, which would result in a smoother flow with less interruptions and inventory piling up.

5.4 Future State Map

The future state is described with the seven questions in the previous subchapter and is illustrated in Figure 22. The three processes where the order is validated, confirmed and firmed are suggested to be merged by forming groups of people from different departments, to minimize waiting times in the communication. Instead of pushing the flow forward, a FIFO principle is suggested to be implemented in the order management processes. By doing that, the lead times and the communication can be improved. The potential %C&A value can also become higher due to the improved communication and the amount of rework can be reduced.

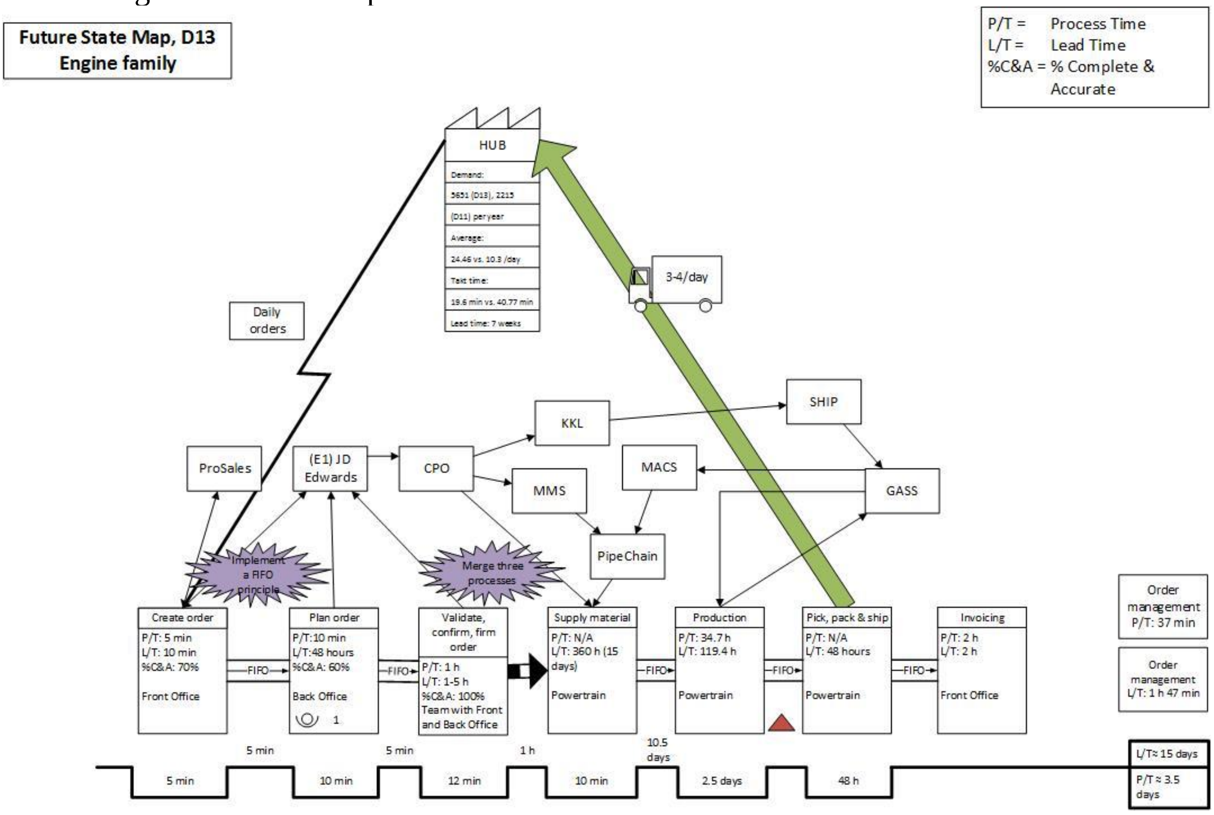

Figure 22. Future State Map

6 DISCUSSION

The discussion section of this study will link the findings with the purpose and the research questions of the project. Suggestions and ideas to develop the study further and to improve the work flow connected to the value chain of the considered engine families are presented, along with thoughts on the possibilities to expand the scope of the study.

6.1 Question 1 – Performance of Volvo Penta

"How does Volvo Penta define and measure their performance in their value chain and how does it differ from the literature?"

Since Volvo Penta is outsourcing the entire production process of the two considered engine families to other actors in the Volvo Group (Powertrain), the detachment between Volvo Penta performance management and the production becomes apparent. Although a big fraction of the responsibility of delivering the right product at the right time lies in the hands of the production facilities, Volvo Penta has the control of the expected outcomes. Volvo Penta measures the short-term performance mainly in terms of lead times and delivery precision, as they are applicable to both the production and the administrative processes. Delivery precision and lead time are common indicators of performance and can easily be benchmarked against similar industries to evaluate the internal processes. Another measure that indicates how well the company keeps its promises to the customers, is the service level. Service level is measured by the Back Office, the supply chain functions of Volvo Penta, and is similar to the delivery precision with the difference of focusing on the fulfilment of target lead times, instead of disturbances in the confirmed orders.

The service level for the industrial D11 and D13 engine families was during the first three periods of year 2019 lower than the target service level and efforts should be put in by all involved parties to increase those numbers. Looking into the delivery precision of the production facilities, a noticeable difference was detected between the overall delivery precision of Powertrain Vénissieux and the delivery precision for the Volvo Penta engines that they manufacture and ship out. During 2018, only 88.4% of the Volvo Penta engines were produced in time, and the main reason was material shortage. To avoid delays in the future, better communications between the Volvo Penta office, the customers and the production is needed. Changes in customer demands and quantity modifications by Volvo Penta leads to disturbances in the order planning and the production at Powertrain Vénissieux. The number of delayed engines at the Skövde facility was not obtained, although the interviewees gave an impression of Volvo Penta engines being more complex and time consuming than other engines.

According to literature, it is beneficial to separate different performance measures in four different levels: Key Result Indicators (KRI), Result Indicators (RI), Key Performance Indicators (KPI) and Performance Indicators (PI). This enables the organization at different levels to understand the weight of the performance measures, since all four types correspond to different significance levels, meaning that some of them are more crucial than others to the survival of the company. All departments at Volvo Penta have defined their own goals and performance measures and formed strategies to reach the goals within the set timeframes. By making the employees aware of the Key Performance Indicators (KPIs) of the business, which indicate the overall condition of the company, they will know what actions are needed in order to affect the performance considerably. KPIs unite the strategies of the different departments and makes it possible for big organizations to see mutual goals, driving the employees and the managers to see the processes from a macro perspective. Performance Indicators (PIs) on the other hand, reflect how particular teams are performing and they work as feedback for the teams for planning what actions they need to take to improve their performance. It is common that teams focus on PIs making them distant from the main goals of the company. By involving the teams in working for a united goal for the company, the customer will be in focus, the flow efficiency will improve, and the waste of underutilized people can be decreased, since they will have the chance to contribute to the overall performance. Managers that motivate their teams produce better outcomes and engages the teams into reaching for results that foster the development of the company.

Other important factors related to the performance of the company, are the total expenses and the cost per unit, which are important to bear in mind since the economic growth of the company is a significant contributor to the profit of the company. The assessment of costs and profits are not included in this study, but they are understandably two of the biggest motives for the company, which leads to the next question that is the fundamental reason behind this study.

6.2 Question 2 – The Effect of Stage V

"In what way does Stage V affect Volvo Penta's value chain and performance?"

The value chain of the engine families that has been studied, includes all activities, both value adding and non-value adding. These activities have been followed to detect any effects resulting from the new legislation, Stage V. Stage V helped Volvo Penta discover that the total cost of the product is difficult to lower without any bad consequences, therefore, Volvo Penta was encouraged to investigate how Stage V affects the performance of the company in other aspects. After many years of focusing on the product cost and attempting to squeeze the prices of services and components in the engine, the focus has been shifted to the process cost and the synchronization of the activities related to the product.

The implementation of Stage V challenges the research and development areas of Volvo Penta, since they are responsible of designing sustainable engines while not exceeding the budgets that has been set. Since Volvo Penta has been focusing on the product price more than the process cost, instead of pushing down prices of components, the focus should be on relations between the suppliers, product development and the production, to increase quality of the product and also improving the responsiveness to the market. This means that quality problems will be detected and solved earlier and faster, ergonomic solutions for the assembly can be developed through collaboration between all the parties involved in the early stages of the product, and the suppliers will be more reliable and adaptable to changes. By doing that, changes like Stage V or other regulations will be less heavy to adapt to.

While interviewing employees at Volvo Penta, the majority of the interviewees gave an impression of seeing Volvo Penta as producers of high-quality and durable engines, which makes the focus on quality even more important. Customers are willing to pay for qualitative, durable and sustainable engines, and expect a high-class service level and the lowest possible level of quality issues. Supplier involvement in the product development process has been shown to be a successful way of creating innovative solutions for products, since the suppliers' expertise and knowledge is dedicated to their products. That means that they are more suitable in determining which choice of material is the optimal one, how the components can be developed in order to improve the assembly or the quality of the product, and how ideas can be developed into finished products with shorter lead times.

Integrating the suppliers in the processes can also lead to other advantages like being prioritized as their customer, motivating them to deliver in time, prioritizing the Volvo Penta orders and allowing Volvo Penta to set higher standards for environmentally sustainable solutions. The emission regulations are constantly updated, which means that new restrictions do not come as surprises to engine manufacturers. Knowing that, progressing faster than the regulations and being ahead of the competitors is an asset for Volvo Penta.

Shortage of material was the biggest issue for Powertrain Vénissieux regarding the delayed Volvo Penta engines, and a potential solution is to work on the interaction between the suppliers, Powertrain Vénissieux and their maintenance managers and the product development at Volvo Penta. The procurement of material at Powertrain Vénissieux could not always be made in time, due to the forecasts not matching the customer demand and the changes made on orders at late stages as preliminary and firm. The purchasing department and the procurement at Volvo Penta and Powertrain Vénissieux can together agree on suppliers that are potential business partners and involving them in the processes allowing them to give and receive feedback. Defects on the components leading to discarding of material is a costly problem accompanied by the problem with shortage of material that leads to long delays. The maintenance managers at Powertrain are aware of the issues with the quantity and quality of the material, which makes them valuable advisers to suppliers and the product development. The suppliers in turn need to pay attention to the problems and create innovative solutions, helping the product development design sustainable products. The three mentioned parties are very important to the quality of the product, and that is why the communication between them is crucial, especially for a company that aims for high-quality products. The strengthened relationships between he parties can give a result of shorter lead times.

The administration of orders involves several different processes that are required to forward order inquiries in the right shape to the factories. The procedures to handle the orders have not been affected by Stage V according to the employees at the Volvo Penta office, however, issues coming from incorrect orders and production problems need to be reported to the customers, which is done by the Front Office at Volvo Penta. The risk of receiving incorrect orders after Stage V has been completely implemented will probably become higher since the number of possible combinations in the engines also will increase. The reasons behind incorrect orders are that customers can choose features of the engines that are not compatible, the engine type can be illegal in some specific geographical area due to emission restrictions etc. or that the systems currently allow incompatible combinations. Since the customers can either enter their orders by themselves or with support from sales persons located in their geographical areas, the support can be offered in a greater extent to help the customers. Another, more common, reason behind orders becoming incorrect after they have been entered, is that DCNs can take effect in between order entry and production, which means that the orders need to be re-entered and handled again. The discovery of these problems can occur as late as at the Powertrain Order Office, which means that many of the orders already have been firmed and frozen. This leads to long waiting times for the customers, unaware of the issues.

By monitoring the orders through all status updates, issues have a higher chance of being detected and solved. An implementation of a smooth flow and a pull system in the Volvo Penta office makes them more flexible and responsive to any deviations. The processes will be more focused on particular orders, enhancing the customer experience. Focusing on the unit in the flow improves the flow efficiency of the processes and can therefore decrease lead times.

Currently, there is a problem with Volvo Penta engines at Powertrain Vénissieux, with delayed engines. Since the production of Stage V engines had not started during this study, eventual problems arising from them have not been assessed. It seemed as the delays would remain for Stage V engines if something is not changed in the communication between Volvo Penta and Powertrain Vénissieux. This problem can also partially be solved with the help of the suppliers, allowing them to find solutions for the high variation among components. When engineering design changes are made and DCNs are sent to the factories, the new versions of the engines do not always imply phasing out of the old articles but can in some cases bring additional articles to the total number of articles and components for Volvo Penta engines. The possibility to customize the engines resulting in high variation among engines is one of Volvo Penta's greatest strengths, but the variation among the total number of articles can be reduced without dropping the diverseness. The production team leaders consider the number of articles too big and some of the engines very complex to assemble, and suggested Poka-yoke (mistake proofing) designs for the components and the engines, to be able to use the same components or tools for different engine types. This leads to avoiding mistakes by standardizing work. To keep up with the market pace, the suppliers should be involved at an early stage to develop new solutions and to be able to phase out old articles.

6.3 Question 3 – How to Optimize the Order to Delivery Process

"What activities affect Volvo Penta's performance of the OTD process and how can they be managed and optimized?"

Nearly all activities within an organization affects the performance of the Order to Delivery process, some more indirectly than others, meaning that processes performed before an order receival from a customer, and after the delivery, also have an impact on the outcome. How the OTD process is constructed has much to do with the entire supply chain of the products, which this study aims to highlight and emphasize.

6.3.1 Performance Measures Guiding the Organization

The performance of the OTD process can be defined with different measures; one of the significant measures that reflect the efficiency and effectiveness of the OTD process is the delivery precision. Aiming for 100% delivery precision to satisfy the customers helps the organization to reevaluate existing activities and makes the managers analyze the factors affecting any eventual insufficient delivery precision. A complete delivery precision has a large number of ingredients, and by measuring the performance of the company in a proper way, the strategies and methods to improve the precision will become clearer. As declared in the first discussion question, the separation of different indicators (KPI, PI, KRI & RI) is useful to generate awareness of the importance of the indicators and to trace it back to the responsible unit. Since the number of delayed Volvo Penta engines in Powertrain Vénissieux is relatively high, the causes for the delays should be found and eliminated by tracing it back to other performance measures that indicate insufficient processes.

Other indicators that show how well the OTD process is performing are Order Fill Rate, Service Level and the Forecast Accuracy, which should be starting points for creating new indicators that can be traced to specific departments. The advantage of doing that is to make sure that the strategies of the departments align with the overall strategies and can be managed on the three different levels of planning of control (Strategic level, Tactical level and Operative Level).

A measure that should be incorporated for the internal processes is Order Entry Accuracy, to present the number of orders that has been entered in a correct way. This indicator should be used to prevent any problems at an early stage. This indicator could also be developed into other measures, like for instance order accuracy at different status updates, to eliminate order cancellations due to failure of technical order validation. By doing that, the %C&A (complete and accurate) can be increased, allowing the forthcoming processes to start their work with less rework and changeover time.

The outsourcing of the production to other entities in the Volvo Group can lead to mismatches in the performance measures with mutual variables. A development of unifying measures between Volvo Penta and the Powertrain facilities can bring a more holistic view of the entire value chain of the products. Important to point out, is that the mutual variables in any eventual unifying performance measures should be matching. An example is that when calculating the total number of engines ordered, the factories did not measure the quantity with the same approach as Volvo Penta. When the quantities were requested from the Powertrain facilities, they presented a higher number of engines, including the subassembly engines that are sent to other factories for complementary assembly. The total quantity obtained from the Volvo Penta office only included the total number of sold and complete engines, making the number much lower. In this study, the quantity that has been used to calculate the takt time is the number obtained from the Powertrain facilities, to build a common thread between this study and another study conducted at Volvo Penta focused only at the production. Thus, the indicators that connect Volvo Penta with Powertrain need to be reviewed to assure that the input data is correct and comparable with Powertrain.

6.3.2 Optimizing Order Administration for Better Flow Efficiency

During the VSM process, it was discovered that the administrative processes are not as simple to follow as when observing the production processes. The reasons are that most of the processes are not visible for the eye and that the information flow moves in all possible directions. The variation in the OTD process is very high, due to the fact that the orders require different amounts of attention depending on the resources and factors determined by the customers. There are orders that go through all administrative processes automatically and also orders that need manual handling at different stages and status updates. The focus during this study has been mainly on orders that go through manual processes.

The order responsibility is divided between different departments at the Volvo Penta office, making the flexibility in the workplace rather low. This leads to high resource efficiency but not the highest possible flow efficiency. Flow efficiency should be the aim for the administrative processes, to maximize value for the customer. This implies increased focus on the unit in the flow, instead of solely maximizing the utilization of all resources. The flexibility in the working culture can be increased by developing cross functional teams, broadening the knowledge of the team members to establish good team work. Currently, the process steps are performed by different departments which means that some changeover time is required every time an order is handled. The changeover time comes from repetitive need to study the order and the customer, to understand what the eventual issues originate from, what the geographical area of the customer is and other details in the order, like the engine's area of application and other specific requirements. A suggestion is to form teams that can focus on a limited number of orders, allowing the orders to go through an efficient flow. So that parallel teams and parallel flows can emerge. The traditional separation of the order responsibilities into the Front Office and a Back Office should be re-evaluated, to increase the understanding of the Order to Delivery process among the employees and departments. The value creating seen from the customer's perspective is very significant since the customer relations are important for Volvo Penta. By forming cross functional teams, the teams are going to be able to distinguish orders with different urgency levels, for instance regarding customers that have strict plans that require engines in time for a project etc. By merging some of the process steps in an appropriate way, the lead time for order administration will be shorter and the customer satisfaction will be higher. This leads to faster order acknowledgements, which currently can be time consuming due to several approvals and processes.

More concrete steps towards improvements in the order administration area are combining the order creation and order planning steps and allowing the Front Office to book transports in some cases, instead of always contacting the Delivery Handler, which in turn needs to contact Volvo PL (Production Logistics). The current situation requires a separation between the order creation and the order planning step, since they are handled by different departments, but by forming dedicated teams that have the possibility to focus on a limited number of customers or orders, the order could be planned instantly after detecting the difficulty of meeting requested date for the engines. By forming such teams, the working titles, responsibilities and hierarchy levels can be evened out in the organization. The workload at the order planning step is currently relatively high and leads to bottlenecks and orders piling up before this process step. This problem should be solved in order to improve the flow efficiency in the Volvo Penta office. An important question to repeat continually is whether we are doing the right things, in the right order with the best possible outcome.

Another issue that makes the distance between the processes larger, is that each department has its specific IT-systems that they are dedicated to, and the possibility to follow an order through all its status updates is impossible in the system "Prosales" (contains sales orders entered by customers), that the Front Office mainly operates in. Since the Front Office is mainly responsible for the order administration, it is important that they are aware of the status updates of the orders and have the possibility and time to follow an order with minimal changeover time, which includes constant switching between IT-systems. The problem with a high level of manual communication in form of e-mails and telephone calls leads to long waiting times between the processes, which lets the customer wait even longer for an order acknowledgement.

The flow efficiency can also be improved in the production, with the help of the administrative processes. To avoid disturbances in the production flow, the production suggested leveling the mix of engines (3.4.6. Heijunka) to make the flow smoother by switching from heavy assembly to simpler engines periodically. The Volvo Penta office can support the leveling of the engines by smoothing the complexity variation of the engines through distributing orders evenly without compromising the target lead times and delivery dates.

The current division of tasks results in suboptimizing the processes, instead of optimizing the entire value flow. By maintaining the focus on the customers and their needs, the methods to create value become clearer for the organization and helps it to form the right product and service for the customers. As Seth Godin once said, “Don’t find customers for your products, find products for your customers.”.

6.3.3 Avoiding Shortage of Material

The shortage of material that was found to be the main reason behind delayed engines at Powertrain Vénissieux affects the OTD process both indirectly and directly. The root causes of insufficient quantities of material and components have been discussed at Powertrain Vénissieux, and the simplest explanation is that they do not always have enough time to procure material within the timeframe that the suppliers have set. The managers at Powertrain Vénissieux have followed the 5-why approach to find the underlying problems behind delayed engines and found that Volvo Penta controls a big portion of the issue.

The procurement department at Powertrain Skövde suggested that the purchasing department at Volvo Penta, which chooses the suppliers, can collaborate with the procurement at the Powertrain facilities to attempt to shorten the lead times from suppliers. Which can solve the problem with changes in the order quantities with a short notice, since the procurement department usually needs enough time to order parts from suppliers.

Within the production, the variation in complexity in Volvo Penta engines results in high fluctuations in the production, which could be solved by leveling the orders (Heijunka). Except the disturbances in the production flow that are partly caused by the fluctuations, the material demands variate as much, which means that the procurement of material becomes irregular. A term used in supply chain, the Bullwhip Effect, explains the effects of the irregular waves of demand. It implies that fluctuations in customer demand leads to bigger reactions to the variations the farther away they get. The fluctuation can initially be relatively small, but as the information moves further up in the supply chain, the reaction to the fluctuation gradually becomes bigger. An increase in demand with a number of products leads to an increase in the production, which in turn leads to ordering even more material, and so on. The problem with causing a Bullwhip Effect is that inventory levels can become very high because of too big reactions to demand increasement and subsequently lowering the ordered quantity in reaction to the high inventory levels, which in turn can lead to shortage of material. To avoid these problems, the forecast accuracy needs to be improved and the leveling of orders considered. Another factor that should be included in the forecasts is the forecasting of kits, which currently leads to issues with engines waiting for kits, causing delays. An approach to achieve more accurate forecasts is to cooperate with the customers and see how their sales are going. The Volvo Penta forecasts can then be partly based on the number of orders that their customers receive. An example of a customer could be a company that produces different machines with Volvo Penta engines.

The integration of suppliers in the business processes is once again important. Except from collaborating with them to design innovative solutions, good relations with the suppliers result in reliability and prioritizing Volvo Penta deliveries. By either making new agreements that shrink the lead times for material or developing new relations with other suppliers, the lead times can be shortened in order to increase flexibility for Powertrain.

7 CONCLUSIONS

In this concluding part of the study, the main discoveries are presented in a summarized form along with a reflection of the obtained results in relation to the purpose and the validity of the study. For the possibility to assess the previously mentioned bottlenecks in the work flow, recommendations for future research have been presented.

The main purpose of this study was to present an overall view of the processes connected to D11 and D13 engine families of Volvo Penta. This was done to give an understanding of the business and to assess how the performance of the company can be improved. In order to support the process of improving the performance, the main problems affecting the value flow have been distinguished, along with suggestions for solutions and approaches to deal with the issues. Due to time and resource limits of this study, boundaries have been set to focus on the scope of this study, which means that other potential improvement areas have been detected and presented in this concluding part.

The main problems affecting the performance of Volvo Penta detected during the study are:

- Delayed Volvo Penta engines at Powertrain Vénissieux due to missing parts/material (new parts/articles in the altered engine structure not announced on time), disturbance in production (mainly when engines are sent through a hot test), change of needs from customers (Volvo Penta changing the requested quantity) and delivery problems (prepared trucks waiting for departure blocked by other trucks etc.)

- The flow efficiency in the administrative processes can be improved. It is partly affected by suboptimized departments.

Possible solutions for the mentioned problems are:

- Improving the communication between Volvo Penta product development, maintenance and the suppliers. By involving the suppliers early in the processes as a long term solution, their creative solutions and devotion can foster Volvo Penta's development.

- Cross functional teams in Volvo Penta's office (mainly the order administration functions), enabling the employees to improve their teamwork and reduce the level of manual communication through e-mails and telephone calls.

To find additional approaches to improve the internal and external processes of Volvo Penta, this study can be elaborated in different ways. The results, validity and reliability of this study and similar projects can be improved by:

- Participant observation as a research method, which means that the research-worker is employed during the study and merged into the observed group

- Preparing all involved parties for the upcoming study, to give them the possibility to plan their allocation of resources

- Considering the financial aspects related to the business

To improve other aspects of Volvo Penta's performance, other interesting areas are suggested for future research:

- Separate and organize the performance measures into different subcategories (KPI, PI, KRI, RI) and divide them into different importance levels. Determine which level of planning of control each one corresponds to (Strategic level, Tactical level or Operative level). Develop new indicators reflecting the performance of the Order to Delivery process.

- Integration of suppliers into different phases in the product lifecycle: product development, production of product and procurement of material.

- Assess the financial performance of Volvo Penta including benchmarking to other actors in the industry.

- Study the value flow of engines for marine use, since they appeared to be more complex and difficult to forecast due to the quantities depending on trends. Also, the financial losses coming from marine engines seemed to be higher, due to the fact that they more often are customized to the specific customer, making the orders more difficult to cancel the closer to the production date they get.

- Investigate if the locations of the hubs (types of distribution centers) are optimal and connect with different customer segments. A study regarding customer segmentation has recently been conducted at Volvo Penta and future studies can be based upon that project.

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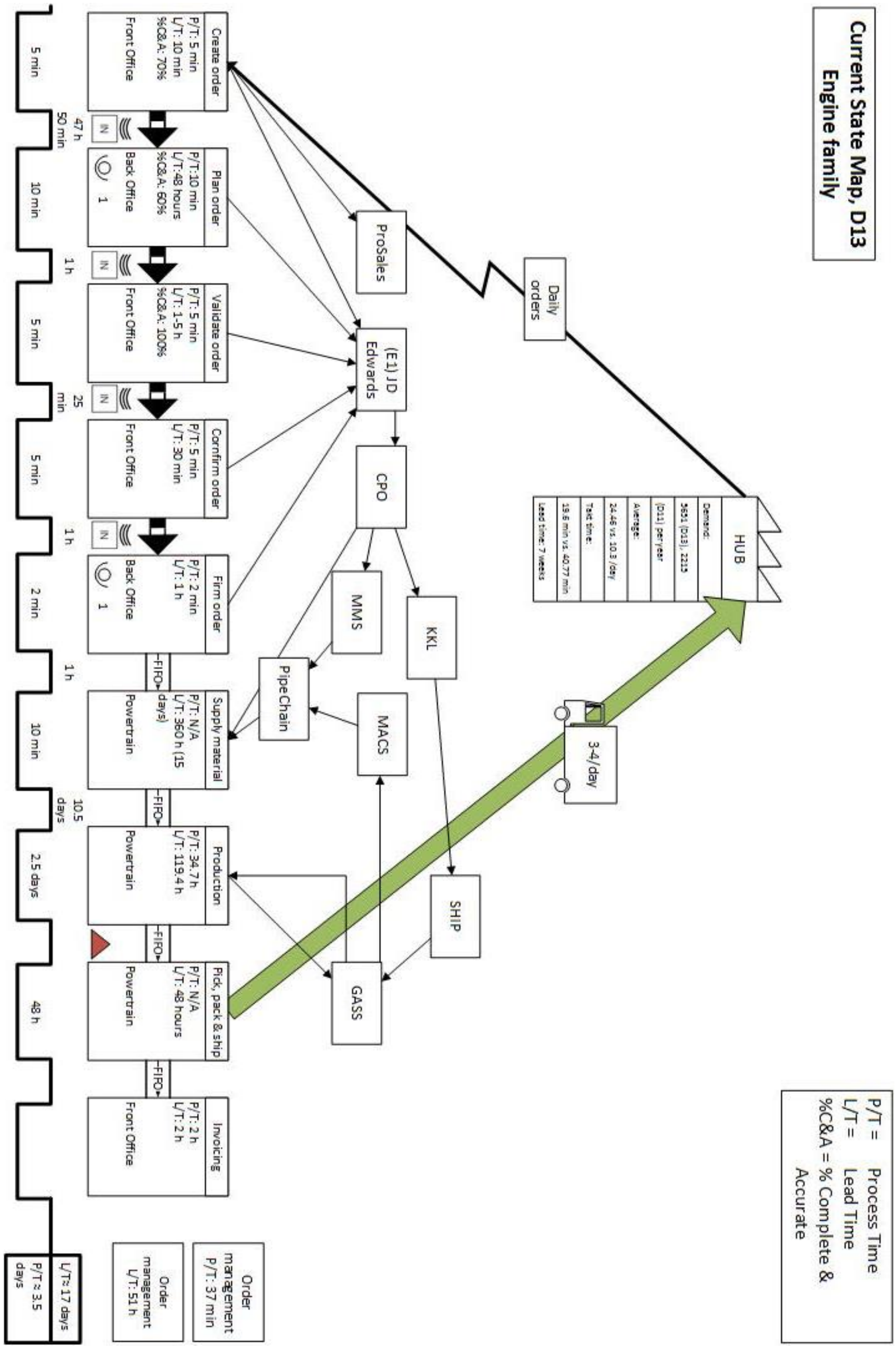
APPENDIX 1 – CURRENT STATE MAP



APPENDIX 2 – FUTURE STATE MAP