Implementing full inventory control in a production facility: a case study at Scania CV Engine Assembly

Bachelor thesis work
15 credits, Basic Level

Product and process development
Production and Logistics

Fuad Dipa & Erkan Ektiren
Abstract

The concept of inventory control has been around since the early 20th century and it’s constantly evolving. The importance of inventory management and supply chain management is clear, and companies are constantly trying to evolve their systems and ways of handling inventory control. By having a proper inventory control system with adequate inventory record audits, a company could potentially have several benefits such as reduced tied-up capital, reduced holding costs, reduced/redistributed work hours, better automation and more.

Most organisations and companies have some form of inventory control, however not all have full control of their inventory. This includes automatic inventory balance updates, package traceability, automatic replenishment systems and more. To implement these ideas, a company would need to foremost find what factors are currently hindering them from obtaining this and consequently being able to adjust their factors. Since there are several ways to obtain an automatic inventory record update that is adequate, multiple proposals are discussed in this thesis project.

This thesis project assessed what the necessary steps that a company needs to perform are through a case study at Scania CV Engine and a benchmarking at Scania Production Angers. Through a collection of scientific literature and empirical data, an attempt to identify the factors that determine whether a company can implement full inventory control or not was made. As a supplement to this, this thesis project also looked over what type of consequences an implementation of full inventory control could have in a company, both when it comes to purely systemic consequences as well as economic consequences.

Keywords: Inventory Control, Automation, Industry 4.0, Inventory Management, Supply Chain Management, Lean.

Sammanfattning

Begreppet saldokontroll har cirkulerat sedan början av 1900-talet och teorierna utvecklas ständigt. Betydelsen av lagerstyrning och Supply Chain Management är idag tydlig och företag försöker ständigt utveckla sina system och sätt att hantera saldokontroll på. Genom att ha ordentlig saldokontroll med adekvata lagerregisteringsrevisioner kan ett företag potentiellt få flertalet fördelar som till exempel reducerat bundet kapital, minskade innehavskostnader, reducerade eller omfördelade arbetstimmar, bättre automatisering och mera.

De flesta organisationer och företag har någon form av lagerkontroll, men inte alla har 100% kontroll över sina inventeringar. Detta inkluderar automatiska lagerrevisioner, spårbarhet av paket, automatiska påfyllningssystem och mer. För att genomföra dessa idéer måste ett företag framför allt finna vilka faktorer som för närvarande förhindrar dem från att uppnå 100% saldokontroll och följaktligen kunna justera dessa faktorer. Eftersom det finns flera sätt att uppnå automatiska revisioner av inventeringen som är proper så diskuteras flera förslag i denna avhandling.

Denna avhandling försöker bedöma vilka nödvändiga steg som ett företag behöver genomföra är genom en utförd fallstudie på Scania CV Engine tillsammans med en benchmarking på Scania Production Angers. Genom en samling av vetenskapliga studier och empiriska data från fallstudien gjordes ett försök att identifiera de faktorer som avgöra om ett företag kan implementera 100% saldokontroll eller inte. Som ett komplement till detta ser denna rapport även över vilken typ av konsekvenser en sådan implementering kan innebära, båda när det gäller rent systematiska förändringar samt ekonomiska förändringar.

Keywords: Inventory Control, Automation, Industry 4.0, Inventory Management, Supply Chain Management, Lean.
ACKNOWLEDGEMENTS

Foremost, we would like to express our special thanks of gratitude to DELT at Scania CV Engine for providing us with the opportunity to conduct this bachelor thesis study in partnership with them. This study wouldn’t exist without them and we are very grateful for all the amazing experiences and learning opportunities we’ve had while working together. We had the chance to meet many of the fantastic and helpful employees at DELT however, there were some that stood out and participated more than others in this study. We would like to thank those people for their expertise, support and helpfulness of which they provided us throughout the entirety of the project. One of them is David Rydberg, who was our supervisor at Scania for this project. Without your help and support this bachelor thesis would not be possible. We would also like to express our gratitude towards Michael Afrem, Radmila Stokic, Tariq Azzo and Igor Sakota.

The three years of studies at Mälardalen University have prepared us for this thesis and if it wasn’t for the amazing teachers at our university, we never would’ve been able to conduct this study. There is however one person that stood out significantly for us during the time period of the thesis and that is our supervisor from Mälardalen University, Anders Hellström. We sincerely thank you for your guidance throughout the entire process and we are grateful for all the knowledge that you passed onto us.

Lastly, we would like to thank all our friends and family that have supported us during our three years of studies. Thanks to all your incredible amount of support, love and positive energy we have been able to keep fighting through.

Erkan Ektiren

Fuad Dipa

Eskilstuna, August 2019
Table of contents

Abbreviations .............................................................................................................................. VII

Chapter 1: Introduction .............................................................................................................. 1
  1.1 Background ....................................................................................................................... 1
  1.2 Problem formulation ......................................................................................................... 2
  1.3 Purpose & Aim .................................................................................................................. 2
  1.4 Research Questions ......................................................................................................... 2
  1.5 Project limitations ............................................................................................................ 2
  1.6 Target group .................................................................................................................... 2
  1.7 Disposition ....................................................................................................................... 3

Chapter 2: Research methodology .............................................................................................. 4
  2.1 Research purpose ............................................................................................................. 4
    2.1.1 Exploratory ................................................................................................................ 4
    2.1.2 Descriptive ................................................................................................................ 4
    2.1.3 Explanatory ............................................................................................................... 4
    2.1.4 Method used in this thesis ......................................................................................... 5
  2.2 Research approach ......................................................................................................... 5
    2.2.1 Deductive approach ................................................................................................. 5
  2.3 Quantitative and qualitative ........................................................................................... 5
    2.3.1 Quantitative methods ............................................................................................... 5
    2.3.2 Qualitative methods ............................................................................................... 6
  2.4 Data collection ................................................................................................................. 6
    2.4.1 Interviews ................................................................................................................ 6
    2.4.2 Observations ............................................................................................................ 6
    2.4.3 Literature Studies ..................................................................................................... 6
    2.4.4 Benchmarking .......................................................................................................... 7
    2.4.5 Case Studies ............................................................................................................. 8
    2.4.6 Primary and secondary data .................................................................................... 8
    2.4.7 Methods used for data collection ............................................................................ 8
  2.5 Data analysis methodology ............................................................................................. 8
    2.5.1 SWOT Analysis ........................................................................................................ 8
    2.5.2 Cost-Benefit analysis ............................................................................................... 9
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5.3</td>
<td>Pugh’s Matrix</td>
</tr>
<tr>
<td>2.6</td>
<td>Course of action</td>
</tr>
<tr>
<td>2.7</td>
<td>Credibility</td>
</tr>
<tr>
<td>2.7.1</td>
<td>Reliability</td>
</tr>
<tr>
<td>2.7.2</td>
<td>Validity</td>
</tr>
<tr>
<td>2.7.3</td>
<td>Objectivity</td>
</tr>
<tr>
<td>2.8</td>
<td>Source Criticism</td>
</tr>
<tr>
<td>3.1</td>
<td>Inventory control</td>
</tr>
<tr>
<td>3.1.1</td>
<td>Managing Inventory Records</td>
</tr>
<tr>
<td>3.1.2</td>
<td>Audit and Correction of Balance</td>
</tr>
<tr>
<td>3.1.3</td>
<td>Inventory Control Technologies</td>
</tr>
<tr>
<td>3.2</td>
<td>Current state</td>
</tr>
<tr>
<td>3.2.1</td>
<td>Flow Process Chart</td>
</tr>
<tr>
<td>3.2.2</td>
<td>Process mapping</td>
</tr>
<tr>
<td>3.3</td>
<td>Inventory Costs</td>
</tr>
<tr>
<td>3.3.1</td>
<td>Tied-Up Capital</td>
</tr>
<tr>
<td>3.3.2</td>
<td>Holding Costs</td>
</tr>
<tr>
<td>3.4</td>
<td>Safety Stock</td>
</tr>
<tr>
<td>3.5</td>
<td>Reorder Point &amp; Replenishment</td>
</tr>
<tr>
<td>3.6</td>
<td>Lean Theories</td>
</tr>
<tr>
<td>3.6.1</td>
<td>First In First Out</td>
</tr>
<tr>
<td>3.6.2</td>
<td>Just In Time</td>
</tr>
<tr>
<td>3.6.3</td>
<td>Pull-based Inventory Management</td>
</tr>
<tr>
<td>3.6.4</td>
<td>Kanban</td>
</tr>
<tr>
<td>3.6.5</td>
<td>Lead Time</td>
</tr>
<tr>
<td>3.6.6</td>
<td>5S</td>
</tr>
<tr>
<td>3.6.7</td>
<td>The 7+1 Wastes</td>
</tr>
<tr>
<td>3.7</td>
<td>Miscellaneous Theories</td>
</tr>
<tr>
<td>3.7.1</td>
<td>ABC Analysis</td>
</tr>
<tr>
<td>3.7.2</td>
<td>Net Present value</td>
</tr>
</tbody>
</table>

**Chapter 3: Theoretical framework**

<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>Inventory control</td>
</tr>
<tr>
<td>3.1.1</td>
<td>Managing Inventory Records</td>
</tr>
<tr>
<td>3.1.2</td>
<td>Audit and Correction of Balance</td>
</tr>
<tr>
<td>3.1.3</td>
<td>Inventory Control Technologies</td>
</tr>
<tr>
<td>3.2</td>
<td>Current state</td>
</tr>
<tr>
<td>3.2.1</td>
<td>Flow Process Chart</td>
</tr>
<tr>
<td>3.2.2</td>
<td>Process mapping</td>
</tr>
<tr>
<td>3.3</td>
<td>Inventory Costs</td>
</tr>
<tr>
<td>3.3.1</td>
<td>Tied-Up Capital</td>
</tr>
<tr>
<td>3.3.2</td>
<td>Holding Costs</td>
</tr>
<tr>
<td>3.4</td>
<td>Safety Stock</td>
</tr>
<tr>
<td>3.5</td>
<td>Reorder Point &amp; Replenishment</td>
</tr>
<tr>
<td>3.6</td>
<td>Lean Theories</td>
</tr>
<tr>
<td>3.6.1</td>
<td>First In First Out</td>
</tr>
<tr>
<td>3.6.2</td>
<td>Just In Time</td>
</tr>
<tr>
<td>3.6.3</td>
<td>Pull-based Inventory Management</td>
</tr>
<tr>
<td>3.6.4</td>
<td>Kanban</td>
</tr>
<tr>
<td>3.6.5</td>
<td>Lead Time</td>
</tr>
<tr>
<td>3.6.6</td>
<td>5S</td>
</tr>
<tr>
<td>3.6.7</td>
<td>The 7+1 Wastes</td>
</tr>
<tr>
<td>3.7</td>
<td>Miscellaneous Theories</td>
</tr>
<tr>
<td>3.7.1</td>
<td>ABC Analysis</td>
</tr>
<tr>
<td>3.7.2</td>
<td>Net Present value</td>
</tr>
</tbody>
</table>

**Chapter 4: Empirical findings**
5.4.3 Reordering point ........................................................................................................... 49
5.4.4 Release of Tied Up Capital ............................................................................................ 50
5.4.5 Reduction of Holding Costs .......................................................................................... 51
5.4.6 IT/System Costs Calculation ......................................................................................... 51
5.4.7 Redistribution of working hours .................................................................................... 52
5.4.8 Cost-Benefit Analysis: Proposal 1 .................................................................................. 53
5.4.9 Cost-Benefit Analysis: Proposal 2 .................................................................................. 53
5.4.10 Cost-Benefit Ratio ....................................................................................................... 55
5.4.11 Investment Analysis ..................................................................................................... 55

Chapter 6: Conclusions & recommendations ........................................................................... 57
6.1 Conclusions To Research Questions .................................................................................. 57
6.2 Sources of Errors ................................................................................................................ 58
6.3 Relevance of study in comparison to previous studies ......................................................... 58
6.4 Suggestions for Further Research ...................................................................................... 59

References ............................................................................................................................... 60

Appendices ............................................................................................................................... 64

Box Supply Flow Chart ......................................................................................................... 64
Pallet Supply Flow Chart ......................................................................................................... 65

Table of Figures

Figure 1 - Example of a SWOT Matrix ....................................................................................... 9
Figure 2 - Example of Cost-Benefit Ratio ............................................................................... 9
Figure 3 - Pugh Matrix Example ............................................................................................ 10
Figure 4 - Illustration of Validity & Reliability ....................................................................... 13
Figure 5 - A Typical Barcode .................................................................................................. 16
Figure 6 - Example of a Process Map ...................................................................................... 18
Figure 7 - Illustration of Replenishment and Safety Stock ......................................................... 20
Figure 8 - 5S "Circle" ............................................................................................................. 22
Figure 9 - Steps taken .............................................................................................................. 27
Figure 10 - Current State Flow Process Chart .................................................................... 28
Figure 11 – When the pallet is picked down to consumption level, the inventory balance is deducted .............................................................................................................................. 32
Figure 12 - How SEA envisions their inventory balance deduction should work .................... 33
Figure 13 - Performed Pugh Matrix Analysis for Both Proposals ........................................... 47
Figure 14 - A typical ABC-analysis Inventory Spread .............................................................. 48
# Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBA</td>
<td>Cost-Benefit Analysis</td>
</tr>
<tr>
<td>DE</td>
<td>Engine Assembly Production Unit Scania</td>
</tr>
<tr>
<td>DELT</td>
<td>Engine Assembly Logistics Development Department Scania</td>
</tr>
<tr>
<td>ERP</td>
<td>Enterprise Resource Planning</td>
</tr>
<tr>
<td>ERV</td>
<td>Estimated Replacement Value (The estimated cost of a replica of the equipment/plant)</td>
</tr>
<tr>
<td>FIFO</td>
<td>First In, First Out</td>
</tr>
<tr>
<td>FPC</td>
<td>Flow Process Chart</td>
</tr>
<tr>
<td>ICT</td>
<td>Information Communication Technology</td>
</tr>
<tr>
<td>IDT</td>
<td>School of Innovation, Design and Engineering at Mälardalen University</td>
</tr>
<tr>
<td>JIT</td>
<td>Just In Time</td>
</tr>
<tr>
<td>LC</td>
<td>Scania CV Engine Logistics Centre</td>
</tr>
<tr>
<td>MC</td>
<td>Maintenance Cost</td>
</tr>
<tr>
<td>MDH</td>
<td>Mälardalen University</td>
</tr>
<tr>
<td>NPV</td>
<td>Net Present Value</td>
</tr>
<tr>
<td>PDCA</td>
<td>Plan, Do, Check, Act</td>
</tr>
<tr>
<td>SEA</td>
<td>Scania’s Engine Assembly</td>
</tr>
<tr>
<td>SPA</td>
<td>Scania Production Angers</td>
</tr>
<tr>
<td>SWOT</td>
<td>Strengths, Weaknesses, Opportunities, Threats</td>
</tr>
<tr>
<td>tSEK</td>
<td>One thousand SEK (50 tSEK = 50 000 SEK)</td>
</tr>
</tbody>
</table>
Chapter 1: INTRODUCTION

The following section of the report is designed to give a brief overview of the subject at hand. This is done by discussing the background of the problem and constructing a problem statement, purpose and a few research questions. In this section, the target group is also going to be defined, and the delimitations will be set. The segment is going to be concluded with a clear disposition of all the different chapters of the bachelor thesis to illuminate the reader about the structure of the report.

1.1 BACKGROUND

Lean production is a principle that’s been used worldwide in the industry since the 1990s. The principle of lean production was invented in the 1950s by Ōno Taiichi who worked for Toyota. The concept of lean production is to manage production in a way that allows for short lead times, low costs and high quality. Although lean production proved to be very effective and simple, it has reached a point now where people question whether the lean principles have reached their limit. The market demands have changed into being unpredictable with deviations and it’s one of the reasons why having an order-oriented production is difficult. Since the lean production principles were founded such a long time ago, they don’t consider the possibilities of implementing modern information and communications technology. Industry 4.0 is a term that was created in Germany as a way of describing the implementation of Information Communication Technology (ICT) in today’s production. The reason industry 4.0 exists is to complement the existing lean production in order to create a new futureproof way of managing production. The aim with industry 4.0 is to manage production dynamically and autonomously (Kolberg & Zühlke, 2015).

The importance of Supply Chain Management and a proper Inventory Control is today very clear. The question instead becomes more oriented towards what the best implementation of inventory control is. Potential negative effects that come with having a poor inventory control system, such as tied up capital, work-in-progress products, higher inventory costs and dead stock, creates room for big improvements. As an organization, making sure your inventory control system is up to par with the latest technology and handled in an efficient manner is crucial for freeing up resources that can instead be directed toward investments, development and improvements within the organization. This creates a potential for competitive advantage (Axsäter, 2015).

Albeit inventory management and inventory control are considered “old” and have been used since the early 20th century, it has continued to be an important topic for logistics and production companies around the world. To fully take advantage of an organizations stock and not have any waste, these terminologies need to be mastered in all aspects. While the theories have remained relatively the same, new and modern technologies and computer systems has made it possible to improve inventory control greatly. An aspect of inventory control that every major company strives towards, which is to have full control of the inventory down to individual article location and number, is something that has not been possible up until the last few decades (Axsäter, 2015).
1.2 PROBLEM FORMULATION

Looking at the background of the project, we can start to illuminate our problem formulation. As Axsäter (2015) mentions, having a proper and well-rounded system for inventory control is an ambition that most major production companies wishes to strive towards. If companies fail to achieve a proper inventory control system, this can put restrictions and unnecessary strain on their storage. With this comes costs in the form of holding costs, material costs and tied-up capital as well.

Full inventory support means that a company has full overview of the stock levels down to individual articles and the whereabouts of packages (pallets and boxes). For this to become materialized the capabilities a facility already has must be identified as well together with the necessary changes which would make the implementation of full inventory support a possibility.

1.3 PURPOSE & AIM

The aim of this thesis project is to investigate and identify what the necessary steps are that a production company needs to undertake to make sure their facility can natively support full inventory control. This aim is going to be reached by analysing literature and performing a case study.

1.4 RESEARCH QUESTIONS

- RQ1: What are the necessary steps (changes and alterations) that a production company is required to perform in order to implement full inventory control?
- RQ2: What are the possible consequences and outcomes of implementing full inventory control in a production facility?

1.5 PROJECT DELIMITATIONS

Due to the time-limit of the bachelor’s thesis, which is constituted of 15 academy credits corresponding to 20 weeks of part-time studies, certain delimitations have been set for the project. The case study that is to be performed at a production company has been limited to one of their facilities and one specific working-area. The focus will be of the inventory/material flow, information flow and anything else relevant to the subject of inventory control. Every relevant step, process and movement that the components make inside of the delimitation needs to be considered in order to fully understand the given problem.

1.6 TARGET GROUP

The main target group of this bachelor’s thesis are engineering students, teachers and professors in the field of logistics and production. However, a thesis is supposed to be constructed in such a way that every step is re-creatable and followed fully. Every reader is supposed to understand the
content of the thesis and be able to follow along with every step. This means that the thesis is aimed toward a general population, where an assumption needs to be made that the knowledge around certain terminology and methodology is not necessarily known among the specified target group. Therefore, the level of the language has been adapted accordingly and most subjects need to be explained in detail.

1.7 DISPOSITION

**Table 1 - Disposition of Chapters**

<table>
<thead>
<tr>
<th>Chapter 1 – Introduction</th>
<th>Introduces the subject of inventory control and describes the given problems in general.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapter 2 – Methodology</td>
<td>The methodology chapter describes the different methods chosen to conduct the study.</td>
</tr>
<tr>
<td>Chapter 3 – Theoretical framework</td>
<td>Theoretical framework is where the description of the theoretical basis used in the bachelor thesis is explained.</td>
</tr>
<tr>
<td>Chapter 4 – Empirical findings</td>
<td>Describes all the collected data during the scope of the bachelor’s thesis and how it’s handled.</td>
</tr>
<tr>
<td>Chapter 5 – Analysis</td>
<td>This chapter will analyse the empirical data by comparing it with the theoretical framework. The analysis partly consists of a benchmarking section and a business case section.</td>
</tr>
<tr>
<td>Chapter 6 – Conclusions and recommendations</td>
<td>The last chapter in the thesis will introduce of conclusions together with recommendations for DELT &amp; SEA. In this chapter, the authors should present their conclusion of the collected and analysed data.</td>
</tr>
</tbody>
</table>
Chapter 2: RESEARCH METHODOLOGY

The research methodology section will describe the different methods and approaches in this thesis project. The different methods and approaches will be briefly described and the motivation for picking the specific methods will be explained. Data analysis methods and validity, reliability and objectivity will also be described in this topic.

2.1 RESEARCH PURPOSE

Before conducting a research, one needs to determine what direction the research purpose takes. This decision will impact the project, as it changes how the information is collected, treated and viewed upon. Depending on what type of research is to be conducted in the project, different types of research purposes can be chosen. There are four different types of research purposes that can be used when conducting a study. These are exploratory, descriptive, explanatory and predictive. While there are different approaches, a study is not necessarily restricted to using only one of them (Saander, et al., 2009).

2.1.1 EXPLORATORY

According to Saunders et al. (2009), exploratory studies are aimed towards understanding “what is happening; to seek new insights; to ask questions and to assess phenomena in a new light”. These questions are especially beneficial when trying to illuminate a problem to further understand it, e.g. when you are unsure of the root cause of the problem. Saunders et al. (2009) continues to explain that the time spent on the exploratory part of a study is well spent as it may give validation of whether to continue pursuing a study or not. An important part of exploratory research is the ability and willingness to change the course of the study as new data and new insights is disclosed.

2.1.2 DESCRIPTIVE

The descriptive research objective is, as Saunders et al. (2009) explains: “to portray an accurate profile of persons, events or situations”. Before collecting data, it is necessary to understand the phenomena from which you will collect the data from. However, descriptive research on its own is no good, as you will need to be able to draw conclusions from the data you are describing. This makes the descriptive research a good complement to exploratory or explanatory research (Saander, et al., 2009).

2.1.3 EXPLANATORY

Explanatory research is designed to create links between different variables. The objective here is to study a problem or a situation to be able to explain their relationship. An example, as explained by Saunders et al. (2009) is that the analysis of a collection of quantitative data, gathered from observations and measurements from several machines, shows a relationship between the age of the machine and its corresponding scrap rate.
2.1.4 Method used in this thesis

The research purpose in this thesis is a combination between two different research purposes; the exploratory and the descriptive one. The project almost demands an exploratory starting position to fully understand the nature of the problem that is being faced. The descriptive stance-point is more focused on understanding “what” the studied phenomena is (Saunder, et al., 2009).

2.2 Research approach

Constructing a proper and well-defined research approach is an important part of any research project. Deciding on which route to pick will affect the way you proceed with collecting the theories and empirical data. There are three main research approaches used in research; the deductive, the inductive and the abductive. While the deductive approach involves first building a theoretical foundation to then apply in practical scenarios to efficiently gather in quantitative data, the inductive approach is instead aimed towards constructing new theories based on the gathered data. The last approach, abductive, is a mix of the two previous ones. (Saunder, et al., 2009).

2.2.1 Deductive approach

In philosophy, deductive reasoning is a very common concept. Transferring these ideas into research, an approach that is leaned more towards hypotheses and experiments is formed. In other words, the approach is based on testing theories. This makes the deductive approach perfect for nature science subjects. As this thesis will focus a lot on finding theories and comparing these with reality, the deductive approach fits the type of research that is to be conducted (Saunder, et al., 2009).

2.3 Quantitative and qualitative

Data collection can be divided into two categories, quantitative and qualitative data. They are both appropriate methods to use when collecting data and they can both be used within one study. When the use of both methods is combined it can deepen the knowledge of the data collected and help in interpreting it correctly. This is called data triangulation (Saunder, et al., 2009).

When certain data has been collected it must also be analysed and there are various ways this can be done. Qualitative data can be analysed with qualitative methods and quantitative with quantitative methods. Depending on the type of data that has been collected a method for analysing the data can be chosen. For instance, qualitative data can be analysed in both deductive and inductive ways depending on what type of data has been collected. The same goes for quantitative data (Saunder, et al., 2009).

2.3.1 Quantitative methods

There are 3 types of approaches to quantitative data collection, experimental, inferential and simulation. Conducting an experiment is one way of collecting experimental data, the purpose of experimentation is to try out hypotheses and to see new connections between variables. Inferential data collection can be used to describe a population using methods such as surveys. A survey is a
method where a portion of a population is observed and studied in various ways through questioning and other methods, the studied population then proceeds to represent the entire population as there’s an assumption that the entire population share the same habits and characteristics. Simulation is a way to observe how various conditions can affect a system or a process and the results can be presented in numerical models (Kothari, 2004).

2.3.2 QUALITATIVE METHODS

Qualitative data collection treats areas such as behaviour, opinions and attitudes. Qualitative data collection methods can be used when trying to find reasons for certain behaviour. This differs from the quantitative approach as the collected data using quantitative methods is numerical. Qualitative data is known to be non-numerical and the opposite of quantitative data. Common methods for data collection using a qualitative approach are interviews and group interviews (Kothari, 2004).

2.4 DATA COLLECTION

2.4.1 INTERVIEWS

Interviews can be divided into 3 groups, semi-structured, unstructured and structured interviews. Structured interviews are conducted with the same set of questions for every occasion, the purpose of this method is to provide an identical interview for each interviewee. Semi-structured interviews differ in the sense that the questions may vary between interviews, depending on the answers of the interviewees. This creates an opportunity to delve deeper into the subject at hand. Unstructured interviews don’t have a prepared set of questions, thus meaning that the interviewee has a lot of freedom to reflect upon various themes and topics (Saunder, et al., 2009).

2.4.2 OBSERVATIONS

Observation is a method where the researcher observes subjects of interest in various ways. If a research is based around what people do and how they do it, a good way to study the things they do is by watching them do it. Observation can be done by watching, recording, describing and interpreting the behaviour of people. There are two different ways in which observations can be conducted and the two ways are called participant observation and structured observation. Participant observation is a qualitative method where the researcher takes part in activities of interest for the study and the purpose of this method is to understand the studied subject better. Structured observation is a quantitative method where the researcher observes various behavioural patterns. The purpose is to look at the frequency of certain behavioural patterns (Saunder, et al., 2009).

2.4.3 LITERATURE STUDIES

Bryman (2016) says that a thorough reading of the current available literature material is essential in order to properly address a certain topic. This is because a proper read-through of the current scientific material can help avoid excessive work as a lot of the needed information, theories and collected data might already be readily available. Furthermore, Bryman (2016) explains that it’s crucial to be able to show that there exists a general knowledge about how relevant scientific
material is selected and knowing what the goal of your own research is. A properly conducted literature review is not simply accomplished by interpreting what is written but also by being able to be critical while examining it to be able to bring forth your own arguments and opinions.

Literature that has been used in this thesis project is peer reviewed and has been collected through well-used scientific article databases such as Google Scholar, IEEE Xplore and ABI/INFORM Global. Essential keywords that has been used will be presented in the table below.

**Table 2 - Keywords used for Literature Review**

<table>
<thead>
<tr>
<th>DATABASE</th>
<th>KEYWORDS USED</th>
</tr>
</thead>
<tbody>
<tr>
<td>Google Scholar</td>
<td>Inventory Control, Gap Analysis, SWOT Analysis,</td>
</tr>
<tr>
<td>IEEE Xplore</td>
<td>Inventory Control, Lean, JIT, Performance Gap</td>
</tr>
<tr>
<td>ABI/INFORM Global</td>
<td>Inventory Control, Lean, SWOT Analysis</td>
</tr>
<tr>
<td>MDH Library</td>
<td>Inventory Control, Lean, Pugh matrix, Inventory Costs, Tied-up capital, Holding costs</td>
</tr>
</tbody>
</table>

2.4.4 Benchmarking

Analysing strengths and weaknesses of your competitors, partners and departments is used by many companies to improve on themselves. One way of doing this is by performing benchmarking. Benchmarking is a good tool for businesses to use to analyse procedure, statistics, services and more, in a specified and related environment, to gain more insight into them. Quantitative analytical techniques can then be used in order the interpret the collected data to understand existing relationships from the studied phenomena (Collis & Hussey, 2009). By benchmarking competitors, partners or even another department in the company, a business can create opportunities for improvements and growth. Used properly, one can get the necessary data required to understand why some aspects of a specific organization is better than another, and how to implement these differences for themselves (Delers, et al., 2015).

For companies to not fall behind in a competitive aspect, they must alter their strategies and approaches quickly and be able to meet expectations from customers, existing and potential ones. As an operational and strategic tool, this is where benchmarking comes in handy and can lead to better customer service, an increase in technological development or lower organizational costs, which all eventually lead to value added for the final customer (Delers, et al., 2015). This thesis will use benchmarking as a tool to understand why and where the problems in the current state lies by looking at different systems used by others. By doing this, one can locate the weaknesses and breakpoints.
2.4.5 Case Studies

A case study is a method used for conducting a research where empirical data collection methods are used to gather data. The study revolves around real life events and phenomenon within it. A case study often answers questions such as how, why and what. Case studies can be conducted using multiple data collection methods such as observations, interviews, questionnaires and documentary analysis. Case study strategies are good when working with theories that already exist and they can also lead up to new research questions being created (Saunder, et al., 2009).

2.4.6 Primary and Secondary Data

Primary data is collected with the intention of using it for a study. Primary data is therefore collected by the researcher for specific purposes. The common methods of primary data collection are questionnaires, interviews and observations. Secondary data on the other hand is data collected from various researchers, thus not produced or collected for the specific study itself. Secondary data can be grouped into 3 different types, survey-based data, data compiled from various sources and documentary data (Saunder, et al., 2009).

2.4.7 Methods Used for Data Collection

The data in this thesis report was mostly collected through empirical finding and through findings on the internet. The methods used for data collection consisted of interviews, unplanned discussions, guided tours, observations, documents from the company and scientific literature. The empirical data collected was mostly used to describe the current state at the company, however it was also important when analysing the situation and coming to conclusions. Key words were used in order to find scientific articles and case studies that treated subjects of interest with regards to the study. Libraries were used as a source of data collection since they offer literature that treat interesting subjects.

2.5 Data analysis methodology

This section will discuss the different data analysis methods that will be used in this thesis project. A brief introduction of the analysis method, in conjunction with the reasoning for using the methods, will enlighten the approach and goal of this thesis project.

2.5.1 SWOT Analysis

When the potential candidates for Best Practice have been identified, a proper SWOT (Strengths, Weaknesses, Opportunities, Threats) analysis needs to be performed to visualize and understand the different aspects that may come with the considered practices. Like the name reveal, the method is a great tool for realizing and understanding the different outcomes that may derive from the changes necessary to acquire the specific Best Practice (Salah, 2015). By creating a matrix with the different aspect of the method, one can easily identify organizational and environmental factors that can affect the project. Usually you allude to these as internal and external factors (Gürel, 2017). See figure 2 for an example of how a SWOT matrix can look like.
2.5.2 Cost-Benefit Analysis

A cost-benefit analysis (CBA) is traditionally used in infrastructure and societal projects, where the full focus cannot be on the monetary gains but need to be directed toward the societal gain, environmental gain or other types of gains. A CBA can also be utilized from a logistic/production standpoint. This type of analysis is made by in as well as possible trying to weigh all the projects wins/losses in monetary terms. Consideration for delayed consumption of capital through the calculation of discounting is necessary as well. The main applications for CBA are (David, et al., 2013):

1. Determining whether an investment/decision is robust by comparing the benefits and costs output of the project.
2. Provide a basis for comparing different investments/decision with each other.

An essential part of arrangements before commencing with any project is determining the costs of the project and comparing it with the potential benefits. The financial part of the benefits is vital however it is not alone adequate in deciding what the gains of a certain project is going to be. Financial assessments are important since they ultimately reveal what the financial incentives for a certain project is and non-marketed gains will need to be valued using some form of appraisal method. However, as non-financial improvements of a project are hard to measure as financial gains, since
these outputs of a project won’t (most likely) be sold on a market, these measures can be highly misleading. Because of this, a proper methodology of cost-benefit analysis is needed where all the inputs and outputs (money spent, gains achieved) are considered. For this to be fulfilled, there are usually several factors that are needed to be considered, such as (Asian Development Bank, 2013):

- Initial project costs
- Estimated financial gains
- Risk and uncertainty
- Valuation of non-marketed gains
- Discounting

\[
\text{Cost Benefit Ratio} = \frac{\text{Net benefits}}{\text{Net costs}}
\]

### 2.5.3 Pugh’s Matrix

There are several types of decision-helping tools that can assist groups of people to decide upon smaller or bigger decisions such as weighted points calculation and more. However, Bailey & Lee (2016) says that for more complex problems and situations, it might be beneficial to use a form of selection matrix. One of these selection matrices is the Pugh Matrix which was developed by Stuart Pugh. Pugh developed the matrix as a tool that could compare different design options with a grounded “reference” design (which is usually indicated with the number 0). This way, the best design could be chosen by the group in charge of doing so. This also opens for the ability to take several different aspects of the different options and form them into a hybrid, which would theoretically create the best possible option (Bailey & Lee, 2016).

The Pugh Matrix is a qualitative comparison tool. It utilizes pluses, minuses and “S” instead of the traditional way of weighting the options with numerical values (see fig x). The options are then summarized and evaluated. The tool was initially created for design concept but may be used for most types decision-making, including but not exclusive for industrial logistic and production decisions (Bailey & Lee, 2016).

### 2.6 Course of Action

The first objective was to discuss the project with supervisors both at the company in the case study and at Mälardalen University. One of the supervisors at the company suggested that praxis at the plant would be beneficial in the early stages of the project as the praxis would generate opportunities for discussions and interviews with workers, it would also improve the understanding of the current state at the company.
The second objective was to foresee what methods of data collection would be suitable for this project. Discussions led to the conclusion that qualitative data would be suitable for the early stages of the project, the qualitative data would include both unstructured interviews with workers during the praxis and participation at relevant workstations. Unstructured interviews can help in receiving in-depth answers (Saunder, et al., 2009) and since the workers would be busy working it didn’t seem suitable to construct more formal interviews such as semi-structural interviews. The informality of the unstructured interviews could generate opportunities for other workers to take part in the interview which is exactly what happened during the praxis.

The praxis helped with gaining basic knowledge about the plant and the processes within it, however there were also a lot of new questions that appeared due to the better understanding of the situation. The praxis took part in the early stages of the project, furthermore the new questions that appeared after the praxis still treated basic knowledge and understanding of the situation. Because of this it was decided to continue with the same approach regarding data collection, meaning that unstructured interviews with open-end questions would further be used in the upcoming interviews until the understanding of the situation was good enough to change the approach. The decision to change the approach came at a time where a lot of information had been gathered and it was decided to change the way that the interviews would be conducted in future interviews. The interviews changed from unstructured to semi-structured due to the better understanding of the situation. Semi-structured interviews would be more beneficial since they allow the interviewer to take more control of the interview compared to unstructured interviews where the interviewee has more freedom (Saunder, et al., 2009). Most of the questions that remained were questions concerning why the company worked in the way that they did and there were less questions about how they worked left.

The chosen methods for data analysis in this study were Cost-benefit analysis, SWOT-analysis and Pugh’s-matrix. These methods were found in literature and online whilst searching for suitable analysis methods. The SWOT-analysis was chosen since it could be used to highlight threats and opportunities for possible investment proposals, as well as strengths and weaknesses. Pugh’s matrix was used in addition to the SWOT-analysis as it would further highlight the strengths and weaknesses of the proposals and the differences would be clearly visible in the matrix. The Cost-benefit analysis was chosen since it would highlight the costs and benefits of the possible investments which is something that the other methods don’t highlight in the same way which would make it a good addition to the other methods.

2.7 CREDIBILITY

The credibility of a project is important to validate the results. If the data collection has not been filtered and been appropriately conducted, this can affect the entire discourse of the thesis. To prevent this, a thesis needs to implement theories of validity, reliability and objectivity (Saunder, et al., 2009). In order to keep the credibility of the study at a high level, it was of vast importance to ensure that the data was collected objectively with the use of valid sources and reliable methods. This will be further explained in the upcoming chapters: 2.7.1, 2.7.2 and 2.7.3.
2.7.1 RELIABILITY

Reliability is a term that’s used as a reference for how consistent the findings are when using certain methods of data collection and analysis. A study with reliable methods for data collection and analysis will have the ability to let other people yield the same results whilst using the study as a template and following the same steps as stated in the study. The reliability of a study can be threatened in various ways through different variables. If a questionnaire is conducted, the answers may differ from people depending on what time during the day they answered the questions and in other cases when conducting interviews, the interviewees can be biased in their answers affecting the data collected negatively (Saunder, et al., 2009). The data that was collected in this report was carefully chosen through qualitative methods such as interviews and observations which are methods supported by literature thus increasing the reliability. As (Saunder, et al., 2009) mentioned, some people might give different answers to the same questions since they are biased in their answers. This was taken into consideration when conducting interviews and it was therefore decided to have multiple interviews with different persons in order to get a wide range of answers that could be compared.

2.7.2 VALIDITY

Validity refers to the sources of data collection themselves, meaning that a source with high validity can be trusted as it is what it represents itself to be about. Validity is also exposed to various threats, some interviewees might fear that the answer they give will affect them negatively which leads to the answers being different, hence the result is affected (Saunder, et al., 2009). In order to ensure that the data collected in this report was valid, all collected data in the study was found in scientific articles, in literature found at libraries or at the company in the case study through interviews and observations. As mentioned previously in 2.7.1, in order to increase both validity and reliability several interviews were conducted with multiple persons at the company in order to gain various answers regarding the same questions so they can be compared. Since some people might be biased or afraid to express themselves honestly, multiple interviews were considered a necessity in order to ensure that the data would be kept both valid and reliable.
While collecting data, it is of vast importance to keep objectivity throughout the entire process. This means that as a researcher you mustn’t be selective with the data you collect, and you must make sure that the data is accurate. If the data isn’t collected objectively the accuracy of the data is jeopardized. The validity and reliability of a study increases when the researcher collects data objectively. The objectivity must be maintained throughout the entire study in order to make sure that the conclusions drawn aren’t misrepresentative. It’s also completely unacceptable to fabricate data in any way (Saunders, et al., 2009). In order to keep the objectivity throughout the entire study, it was decided in the early stages of the study to always consider all data important and to not choose or in any way try to fabricate any data collected. There was no selectivity with data collected or in the choice of interviewees. Interviews were conducted with people that had very different approaches and views towards this study.

2.8 **Source Criticism**

The sources that are used in a scientific study need to be critically examined in order to ensure that the collected data is reliable and valid. There are a few things that need to be critically examined regarding the source of collected data. If a source on a website is used to gather information, then it’s important that the written text has been examined by an institute, for instance it can be a scientific institute. It’s important to examine whether the writers are biased in what they write or if the things that are written were influenced by factors such as politics or economics. Another factor that should be considered is whether the source is relevant at the time it’s being used as a source (Blomkvist & Hallin, 2014).
Chapter 3: Theoretical Framework

Theoretical framework will give a thorough overview of the different theoretical topics that will be used in this thesis. The framework creates the “back-bone” of the report, allowing conclusions and analysis be made from the collected empirical data. Theories and terminologies such as the definition of inventory control, lean, waste and more will be presented here together with eventual benefits of said theory.

3.1 Inventory Control

Supply Chain Management, the control of the flow of material from suppliers to customers, is an essential part of almost every organization in the economy sector. A proper use of inventory control allows for potentially less tied up capital which can be used to invest in other aspects of the business. This makes inventory control an extremely important factor to weigh in into your decision making, due to its potential to give competitive advantage. Simultaneously, the risk of a too small inventory can cause costs because of material shortage and other consequences, further increasing the importance of proper inventory control and management (Axsäter, 2015).

Inventory control cannot fully be cut off from other functions in a warehouse such as purchasing, producing and marketing. One of the main goals with inventory control is to create a balance within the business (Axsäter, 2015). Although inventory control seems to be a term thrown around loosely, many people fail to mention the difference between simple inventory control and the broader term of inventory management, with the latter including functions such as forecasting and reordering points (Karim, et al., 2018). As these elements won’t be a topic of this bachelor thesis, it’s imperative to understand the definition and scope of the term inventory control.

Most organizations have the possibility to reduce inventories without the risk of increasing other costs if they make use of efficient inventory control tools. Due to the technological lead lately and the introduction of Industry 4.0, which is defined as the next milestone in industrial technological advancement (Ghobakhloo, 2018), inventory control has become more available and easier to apply than ever. To better understand the inventory control in a warehouse, one needs to implement a practice of proper mapping of the flow of material/goods and information within the confines of the warehouse. Only then can one fully take advantage of the positive aspects of inventory control and the consequences of it; e.g. less tied capital and less occupied storage area. (Axsäter, 2015). Failure to properly and efficiently manage inventory will also create other problems for a company such as decreased productivity, accumulation of inventory handling costs, too much unwanted cost for a company and can even cause moral tensions and frustration within a team (Karim, et al., 2018).

3.1.1 Managing Inventory Records

One of the prerequisites for being able to implement a functional inventory control system is to have all the data available and make sure that the risks of error occurring in the data is small. If
errors occur, automatic orders will be dysfunctional. Therefore, the importance of proper inventory registration procedures is vital for an inventory control system to operate. Every transaction into the balance should be viewed as a possible source of error as they are especially difficult to manage. When an error occurs in the system, it can be present and cause disruption for a long time. Appropriate preventive measures should be in place to stop this from happening. Audits and corrections of the inventory balance is a good way of doing this (Axsäter, 2015).

In sum, good procedures are vital for a good inventory record. However, the biggest issue with keeping inventory records is not necessarily the procedures but rather the trouble lies in following the procedures. According to Axsäter (2015), the most common error there is that transactions take place without being recorded properly. Therefore, all personnel involved in reducing or adding to the inventory balance need to be sufficiently instructed and trained to prevent balance errors.

3.1.2 **Audit and Correction of Balance**

To prevent errors causing too much damage, they need to be found early on. This can be done in several ways. Axsäter (2015) says that all inventory balances should be checked by counting. This can either be done using *periodic counting*, where an annual item count is performed by at least two people. The other way, he mentions, is by *cycle counting*. A limited number of articles and items are checked each day, continuously checking on the stock during the year. This should be done just before replenishment occurs, when the inventory is still low and easier to count. However, others claim that random sample tests of pallets and articles should be enough in order to make sure the total number of articles is correct. A preventive measure for the system to find errors can be to register pallets as empty as well. That way, the system can figure out if too much or too little of an article has been deducted before the package has been emptied, triggering a warning for a possible item count (Ruet & Vitet, 2019).

3.1.3 **Inventory Control Technologies**

There are different types of equipment and systems used to identify, visualize and transmit information between internal systems in a company. A lot of these types of equipment have been readily available in the market for a long time and most companies tend to lean toward the more traditional methods since they’re proofed and shown to work, such as material handling lists and barcode scanners. However, new and modern solutions have appeared in the market. Some of these consist of automatic data collection through equipment such as barcode scanning, RFID-tagging of packages and items and more. While barcode scanners are still very efficient and relevant today, other new and innovative methods and equipment that are available could potentially increase efficiency and save money for companies who decide to implement these new technologies (Axsäter, 2015).
**Barcodes**

Bar codes are 12-digit numbers that contain information which can be read by computers, these codes can be placed on containers, pallets and boxes. Usually a scanner is used in order to convert the information in the bar code to something useful. The information in the barcode can reveal various types of information, for instance it can reveal what type of articles are in a pallet and how many articles are inside the pallet. With the use of a barcode scanner it’s possible to simply scan the barcode and get this useful information straight away. The scanning can be done in two ways as there are two different types of barcode scanners. There are scanners which don’t require contact with the barcode as a laser from the scanner scans the barcode. The other type of scanner is one that requires contact with the barcode in order to retrieve information from the barcode. Barcodes and other types of automatic identification technologies have a lot of benefits to them. They can reduce physical inventory time and labour costs as well as improve traceability for products. They also improve the accuracy of inventory control (Bowersox, et al., 2012).

**Radio Frequency Identification**

Radio Frequency Identification (RFID) is a technology that identifies objects automatically with the use of radio waves. RFID can be implemented by using serial numbers as the identity for objects. The serial number is stored on a microchip that together with an antenna work as an RFID tag. The microchip can send information through the antenna to a reader that converts radio waves and sends them back to the microchip. The reader converts radio waves into information, hence the waves that are sent back are sent as new information (Bakhla, et al., 2018). RFID technology helps computers and machines to distinguish objects and it also records data. The information that it sends can be used to track various objects and articles, it can also be used to identify them. In supply chain management the use of RFID-technology can result in benefits such as a decrease in the stock dimensions and faster responds to client requests (Yadav & Jha, 2019).

There are some advantages with using package tracking with the help of RFID-tags. According to Al-Ani (2015) a proposed system with RFID-tagged packages have a four-part infrastructure. The people who manage the system, the technology needed (RFID-tags, antenna and RFID-reader), the monitoring of packages and a database to hold and interpret all the information. The advantages attainable with this type of system versus a traditional system are:

- Less people working on the system, leading to freed-up working hours.
- Lower cost for checking packages.
- Being able to see number of items in packages.
- Being able to send/see information about defective packages.
- Provide/see relevant package information.
- The ability to monitor the movement of packages inside of the facility.
3.2 CURRENT STATE

Current State is a common terminology used when describing the process of visually and/or in written words portray the selected processes of a business as they currently function. Depending on what is needed to illustrate the current state of the selected process or series of processes, different methods will be used. Common methods used when constructing a Current State are process, material and information mappings, which is going to be utilized in this thesis. By having a clear illustration of the current state, one can with ease identify and analyse the problem areas and eventually come up with suggestions for future states.

3.2.1 FLOW PROCESS CHART

The flow process chart (FPC) was first introduced by Frank B. Gilbreth in 1921 and is a visual tool that is sometimes included in the “seven basic tools” of quality. An FPC is basic process investigation tool that was created in order to better understand processes and find ways to remove or fuse different steps in a process to remove waste. It is most usually utilized by industrial engineers and can be used to reduce average movement, reduce average operation times, improve efficiency in a process chain and more (Soni, et al., 2014).

Standard FPC’s use five different symbols to illustrate the activities within the process-chain which aids in the visualization of the process-chain:

- Circles/ovals, which represent an operation
- Arrows, which represents movement/transportation
- Squares, which represent inspection/quality control
- D (symbol), which represents a delay in the process-chain
- Triangles, which represent storage (Soni, et al., 2014)

3.2.2 PROCESS MAPPING

Process mapping can be a useful tool when working with improvements as it helps workers with determining in what areas there are risks and where they can implement changes and improvements. A few fields where process mapping can be applied are decision-making, identification of risks and opportunities for improvements, problem solving and reasoning (Colligan, et al., 2010). The methods of process mapping were mostly used and understood by engineers and analysts in the past, nowadays however these methods are utilized by all employees at a company (Nash & Poling, 2008).
3.3 INVENTORY COSTS

As previously mentioned, poorly executed inventory control can lead to a variety of ill-beings for a company, large or small. A reorder-point that is too early leads to unnecessary build-up of stock in the inventory, causing costs for storage area, dead stock and tied capital. To prevent unnecessary costs like these, and other costs that could be categorized as part of the 7+1 wastes, a company needs to understand why they occur and how to prevent them (Axsäter, 2015).

3.3.1 TIED-UP CAPITAL

Goods that are placed in an inventory can be viewed as restricted equity capital since the money that was used to purchase the goods is tied to the goods themselves and it can’t be used for any other purposes after the purchase is made. The reason for having goods stored in an inventory is to eventually make economic profit from the goods in one way or another. The money that’s tied to the goods can be released and used for other purposes which might also end up being beneficial from an economic standpoint. Having lots of tied up capital can therefore result in a loss of opportunities and income possibilities. There are also existing risk factors when storing goods in inventories such as the goods being stolen, damaged or outdated (Oskarsson, et al., 2013).

Given that the freed up tied-up capital is calculated by how many packages will be reduced in the inventory and how much the pallets are worth, the benefits of releasing tied-up capital can be calculated with the following formula (Hedvall & Olsson, 2013):
\[(SS_c \times \bar{v} \times SS_n \times \bar{v}) \times IRR\]

### TABLE 3

<table>
<thead>
<tr>
<th>Symbols</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>(SS_c)</td>
<td>Safety Stock Current</td>
</tr>
<tr>
<td>(SS_n)</td>
<td>Safety Stock New</td>
</tr>
<tr>
<td>(\bar{v})</td>
<td>Mean Value</td>
</tr>
<tr>
<td>IRR</td>
<td>Internal Return Rate</td>
</tr>
</tbody>
</table>

### 3.3.2 Holding Costs

When a stock is held, there’s also a cost that comes along with the stock. This cost is known as tied up capital and it isn’t a regular cost as there’s no payment being made technically. Tied up capital is all the money that a company has invested in articles for example, the cost represents the money invested in an article that is in the inventory. This means that the money can’t be used by the company for other purposes, the money invested in the articles is locked to the article. Also, the articles take up space in the inventory which could’ve been used for other purposes as well (Axsäter, 2015).

### 3.4 Safety Stock

Safety stocks exist with the purpose of preventing errors such as production stops in companies. If a company doesn’t have a safety stock, there’s a risk that they will need to stop the production if they face problems such as insufficient amounts of material in the inventory and this can lead to their customers not receiving their orders in time. Errors do occur sometimes in reality, and in order to prevent the errors from causing huge losses to companies, safety stocks can be used as protection (Oskarsson, et al., 2013).

### 3.5 Reorder Point & Replenishment

Replenishment is necessary in order to keep the production up and going. Since replenishment is a necessity there are various ways in which replenishment can be done in order to keep the costs as low as possible and for production to be stable and not shutting down at any time. One key factor to having a replenishment system where a company is provided with goods in a stable way is to have suppliers that can meet the demands of the production at the company. Finding the right suppliers is a process where the company needs to evaluate and search for a lot of potential suppliers with the intentions of signing a contract that is reasonable (Oskarsson, et al., 2013).

To determine the reorder point for a specific article, using safety stock, demand over a period and the lead time (number of periods), the following formula can be utilized (Jonsson, 2008).

\[OP = SS + D_t \times LT_t\]
Table 4

<table>
<thead>
<tr>
<th>Symbols</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>OP</td>
<td>Reorder Point</td>
</tr>
<tr>
<td>SS</td>
<td>Safety Stock</td>
</tr>
<tr>
<td>$D_t$</td>
<td>Demand (period $t$)</td>
</tr>
<tr>
<td>$LT_t$</td>
<td>Leadtime (number of periods)</td>
</tr>
</tbody>
</table>

Figure 7 - Illustration of Replenishment and Safety Stock

3.6 Lean Theories

3.6.1 First In First Out

First-In-First-Out (FIFO) is a principle used in inventory management to efficiently iron out the time in stock for pallets, boxes and articles in storage. The principle is about making sure that packages/items that arrives to the storage first is also the one that leaves the storage first, essentially assuring that all material leaves storage in a chronological order. By implementing this principle in a storage area, one can assure the same time in stock for every pallet/box since the picking-time is the same in a given period (Lumsden, 2012).

Implementing the FIFO-principle in a storage area ensures a proper structure in the given storage. This creates a natural prevention of overproduction if you limit the amount of storage positions for a given article, as it stops the previous process from continuing its production or delivery when the FIFO-lane is fully filled (Rother & Shook, 2003).
The consensus of Just-in-Time (JIT) is that it’s not to be considered a method and rather to be viewed as a philosophy. A philosophy which has an aim to reduce and/or eliminate any excess, whether it is excess in work, material or any other organizational factor. This is not restricted to internal organizational activity, as JIT is generally seen as dividable in two parts: internal and external. The internal work regards anything that has with the manufacturing and flow or material between different processes. In contrast, the external part consists of organizational relationships with customers and suppliers. According to the original philosophy of JIT, one should regard their company as simply a part of a chain, a chain which consists of all the different actors (Ax, 1997).

As a part of the Japanese philosophy of Lean, JIT was used in the production of Toyota vehicles. Through a constant improvement of the production, one can significantly reduce costs by only performing the absolutely required activities in the process chain and thus reduce waste in the organization. Anything that does not offer value-adding processes to the chain is to be eliminated, with non-value-adding processes consisting of everything that is considered a cost that comes with no profit (Ax, 1997).

The most important part of JIT in manufacturing is getting the correct number of items in the correct time. This means creating a balance where you do not deliver or produce too much material, creating unnecessary stock, while at the same time ensuring that there won’t be a deficit of material where it’s needed. This philosophy is usually summarized in a term called “The Seven Rights” (Buhre & Persson, 2007):

“Deliver the right product, in the right quantity and in the right condition, to the right place at the right time for the right customer at the right price” (Encyclopedia of Production and Manufacturing Management, 2000).

One way of managing the material in production can be through pull-based management. Pull-based management means that the flow of material is dependent on a consuming unit which decides the flow of the material. The process is initiated by the consuming unit as it sends out the order for new material, the material proceeds to move according to the orders. Pull also means that orders are placed in a low quantity with the intent of almost having single orders (Jonsson, 2008).

Kanban, which is Japanese for “visual card”, is as the name implies a visual card that indicates a certain process or task has been finished. The card specifies that a replenishment of components or materials is needed for the process to be able to continue working. Usually when thinking about Kanban and Kanban cards, a physical card comes to mind. However, due to the development of IT systems and computers most recent inventory control software’s today have a form of digital Kanban system which automatically sends out orders to replenish a process or workstation. Alternatively, it sends out a signal for workers to see that the material or component is running.
low and a replenishment is needed. This way of working, in a pull-based system, minimizes the necessary inventory and improves an organization’s lean development (Leopold & Kaltenecker, 2015).

3.6.5 Lead Time

Lead time is a measurement that shows how long it takes to process an order. The measurement begins when an order is received, and it ends once the delivery has been made. One order for a product usually doesn’t have one single lead time. There are multiple lead times within the order itself that show for example how long it takes for a forklift to deliver material to a certain destination at the plant. The measuring of the lead time begins once the forklift has received the task to deliver material and the measuring ends when the order has been delivered to the designated location. There are multiple ways to measure lead times, however a common method is to automatically have the time registered both when an order is received and when the order has been delivered (Oskarsson, et al., 2013).

3.6.6 5S

5S is a lean tool that’s used to improve teamwork and eliminate waste that causes injuries, defects and errors. The 5S method consists of 5 activities:

- Sort
- Straighten
- Shine
- Standardize
- Sustain

The first activity called Sort consists of sorting out items in order to throw out the one’s that aren’t needed, this is done in order to clear out the working spaces and create more room as well as to keeping the regularly used items visible and accessible for the workers. The second activity is called Straighten and the purpose of this activity is to organize the working area in such a way that everything is placed ergonomically for the operator. The third activity is Shine and it means that everything should be kept clean and visually inspectable. The fourth activity is to Standardize the first 3 S’s, which means that the 3 S’s should be done frequently with the use of rules or guidelines. The name of the final activity is Sustain, the meaning behind this is to be disciplined with the implemented changes by having regular check-ups and trying to find improvements continuously. One way of keeping the workers disciplined is to hand out rewards to the team that had the best results and performance regarding the changes and activities (Liker, 2004).
3.6.7 **The 7+1 Wastes**

There are 8 wastes often referred to as the 7+1 wastes and they were identified by Toyota (Liker, 2004).

1. **Overproduction** is one type of waste which means that items are produced even when there’s no need for them to be produced. The consequences of overproduction are that the items which were excessively produced need to remain somewhere at the plant as there aren’t any orders for those items. As a result of this the items need to be stored and transported which costs money for both, hence it’s seen as a waste for the company (Liker, 2004).

2. Another type of waste is all the **time wasted on waiting**, the workers that observe an automatic machine are wasting time because they aren’t being productive. All types of time wasting where workers don’t do anything productive is seen as a waste economically as the company pays these workers and they don’t do anything (Liker, 2004).

3. **Unnecessary transportations** are also seen as a waste, they’re inconvenient as more time then what is needed is spent on them (Liker, 2004).

4. **Incorrect processing or over processing** is seen as a waste due to various consequences. A lot of time is wasted when items are processed in more steps then what’s needed. If the tools that are used to process items are in bad condition, it could affect the items and cause defects to appear. The products that are produced shouldn’t hold a higher standard than what’s demanded by the customers (Liker, 2004).

5. **Excess inventories** are viewed as waste because they generate many consequences. The items that are stored excessively can damage other goods and there is also a risk that they will become outdated if they are stored for long periods of time. They also cause long lead times which costs more money (Liker, 2004).

6. **Unnecessary movement** is also seen as a waste, all the time that is wasted on looking for tools, reaching for tools and walking could be used for other purposes that would be more beneficial for the company (Liker, 2004).

7. **Defects** are regarded as waste because they cause a lot of consequences to appear. When defects are detected something needs to be done in order to repair the defective items. Another consequence is that somethings might need to be changed in order to prevent further defective products from being manufactured. All of this is costly and demanding both effort wise and timewise (Liker, 2004).

8. The final waste is that **creativity from employees isn’t being used**. Not utilizing the creativity from workers can lead to a loss of good ideas, time and skills (Liker, 2004).

3.7 **Miscellaneous Theories**

3.7.1 **ABC Analysis**

To maintain high quality inventory management, it is necessary to have different classifications of the given inventory in a warehouse. ABC analysis is an inventory management method which
categorizes different articles based on their share of the annual volume and value. Items are categorized into three different categories: A for the highest dollar volume, B for the mid dollar volume and C for the lowest dollar volume. ABC analysis is deemed an “addition” to something called the 80/20 rule, which says that 80% of a company’s inventory consumptions stems from just a fifth (20%) of the articles. (Smith, 2011)

3.7.2 Net Present Value

Net Present Value (NPV) is an investment calculation method that is designed to determine whether an investment or project is going to be profitable or not. The pros of using the NPV-method is that it considers the change of value of money over the chosen period. By calculating the sum of the present value of incoming and outgoing cash flows (benefits and costs) over a period of \( t \) years, an assessment of the project and its profitability rate can be done. This method can also be used as a way of comparing different projects or investments, with the one yielding the highest NPV usually would be the one the company decides to undertake. A negative NPV means the project is going to make the company lose money, while a positive means they will gain from the project. To use this method however, a company needs to know all their projects incoming and outgoing cashflows, their initial costs and their internal rate of return. The method could also be used to determine the maximum initial cost that can be budgeted for a project before it starts yielding negative results. (Gaspars-Wieloch, 2019)

\[
NPV = -IC + \sum_{t=1}^{n} \frac{C_t}{(1 + IRR)^t}
\]

<table>
<thead>
<tr>
<th>Symbols</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>( NPV )</td>
<td>Net Present Value</td>
</tr>
<tr>
<td>( IC )</td>
<td>Initial cost</td>
</tr>
<tr>
<td>( t )</td>
<td>Time period (year)</td>
</tr>
<tr>
<td>( C_t )</td>
<td>Cashflow (period t)</td>
</tr>
<tr>
<td>( IRR )</td>
<td>Internal Return Rate</td>
</tr>
</tbody>
</table>
Chapter 4: Empirical Findings

This chapter outlines and presents the totality of the relevant empirical data that has been collected during the bachelor’s thesis. The empirical data collected will help develop a current state, where the company’s current logistical and system structure will be presented together with other types of data such as data collected from case studies, benchmarking and interviews, observations and literature studies.

4.1 Case Study

As a part of this thesis project, a case study was performed at Scania CV Engine Assembly in Södertälje. The authors of the thesis worked in close connection with supervisors and employees at Scania to be able to identify and potentially find a solution for their issue of inventory control. This case study will work as a foundation for the thesis.

4.1.1 Background

Scania is a successful production company who today is providing a wide range of transportation solutions. They develop, produce and sell trucks, buses and other transport applications (Scania, 2018). Scania Engine Assembly (SEA) is a part of the Scania Group and is the facility responsible for assembling the different engines that Scania uses for their trucks and buses. The variety of engines they produce generates a need for SEA a wide range of different articles and components. This number is steadily increasing and to be able to meet the continuously generated demand and at the same time keep inventory costs down, the logistics team at SEA wishes to focus more resources towards improving their inventory control systems (Axsäter, 2015).

The Logistics Team in SEA (DELT) wants to improve the way of working with inventory control in their facility. Their system is currently working in batches and pallets, which is satisfactory up until the package has been opened and “consumed” in the system. Their goal is to include inventory control over individual items post-opening. Essentially, this has limited and prevented the SEA facility to having the control they desire over their inventory. They also want a better and clearer system for registering eventual scrap of components, since this process is currently similarly to the before mentioned handles in “batches” and not as individual items.

SEA is currently using several systems that work in synergy with each other. However, they are not used to their full potential. Albeit the systems are natively supporting inventory control, SEA has not managed to connect all the necessary ties to make it work. Several attempts have been made to transition over to full inventory control, but the attempts have failed. Scania wishes to investigate what type of changes are needed to be issued in the factory to improve their inventory management and support full inventory control.
COMPANY HISTORY AND DESCRIPTION

Scania AB as it’s known today was earlier known as Scania-Vabis which was founded in 1911 through a merge between the two companies Scania in Malmö and Vabis in Södertälje. The head office was established in Södertälje after the merge and all the executives moved to the head office along with the leader Per Alfred Nordeman. Scania-Vabis produced engines and cars in Södertälje, trucks and heavier vehicles were produced in Malmö.

Since 2008 Scania has been a part of the Volkswagen group which also consists of brands such as Porsche, Lamborghini and Bentley (Volkswagen, 2019). Scania has more than 50,000 employees worldwide today in more than 100 countries (Scania, 2018).

Scania has a few core values that form their basis of culture, business success and leadership and they are the following:

- **Customer first**
  Scania see their own success as something that is achieved through the success of their customers. The company tries to understand their customers to the maximum possibility in order to make them winners. The efficiency and operation of the customer is of vast importance to Scania as they’re a part of Scania’s value chain (Scania, 2019).

- **Respect for the individual**
  Scania wants their employees to treat each other with mutual respect, meaning that everyone should treat others the same way they’d like to be treated themselves. Scania is a big society with employees that work with different jobs, it’s important to Scania that all the individuals listen to each other and treat one another the same no matter what job the employee does. The company wants to seize the ambition, knowledge and experience of every individual that works for Scania (Scania, 2019).

- **Elimination of waste**
  Scania works with continuous improvements and they use deviations to identify waste and eliminate it. Scania strives to have their resource efficiency and flow optimised both internally and externally, one of the objectives is also to minimize environmental footprints (Scania, 2019).

- **Determination**
  Scania views determination as an important factor that can add value to themselves and their customers. Scania views their challenges as prideful as they want to find innovative solutions to their challenges. All these details will help Scania reach new levels (Scania, 2019).

- **Team spirit**
  Scania strives to be the number one company in their industry and in order to be number one they view teamwork as an essential factor to reach this goal. Everybody at Scania works together
towards a common goal and the company feels positively about diversity as it can help in finding different solutions and opportunities (Scania, 2019).

- Integrity

Scania acknowledges their social responsibility with the goal to do right things in the right way. The acts of the company are always considered from the standpoints of culture, principles and core values. As a result of this, Scania acts with compliance of the law. Scania believes that trust builds relationships and that’s one of the reasons they keep their promises all the time, they always take accountability for their actions as well (Scania, 2019).

4.1.3 Thesis Project Timeline

To make the timeline of the thesis project clearer, a step by step diagram was created. The essential parts of the thesis project are outlined in figure 10.
4.1.4 Current State

4.1.5 Flow Process Chart (Pallets)

1. Definitive from the Logistics Centre to the material handling area in DE and to the vital parts of the processes
2. Either the time is too random to calculate, isn’t relevant, was not possible to find or varied greatly depending on type of article etc.

<table>
<thead>
<tr>
<th>Step #</th>
<th>Time (min)</th>
<th>Distance (meters)</th>
<th>Step Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>?</td>
<td>-</td>
<td>Pallets are located in the Logistics Centre (LC)</td>
</tr>
<tr>
<td>2</td>
<td>?</td>
<td>-</td>
<td>Ordered pallets are sorted and placed in a MAFFI-wagon.</td>
</tr>
<tr>
<td>3</td>
<td>?</td>
<td>-</td>
<td>MAFFI-wagon is transported to DE</td>
</tr>
<tr>
<td>4</td>
<td>0,75</td>
<td>-</td>
<td>Pallets are picked from MAFFI-wagon and sorted</td>
</tr>
<tr>
<td>5</td>
<td>1,9</td>
<td>-</td>
<td>Pallets are transported to their corresponding storage areas</td>
</tr>
<tr>
<td>6</td>
<td>?</td>
<td>-</td>
<td>Pallet is waiting to be picked down to the consumption area</td>
</tr>
<tr>
<td>7</td>
<td>?</td>
<td>-</td>
<td>The pallet is lowered down to consumption level and opened</td>
</tr>
<tr>
<td>8</td>
<td>0,3</td>
<td>-</td>
<td>A material handler receives a kit-wagon</td>
</tr>
<tr>
<td>9</td>
<td>0,4</td>
<td>-</td>
<td>Material handling lists are placed on each of the pockets in the kit-wagon</td>
</tr>
<tr>
<td>10</td>
<td>2,25</td>
<td>-</td>
<td>Articles are placed on the kit-wagon</td>
</tr>
<tr>
<td>11</td>
<td>0,5</td>
<td>-</td>
<td>The articles are tallied, double-checked and the material handling lists are stamped</td>
</tr>
<tr>
<td>12</td>
<td>0,1 –?</td>
<td>-</td>
<td>The kit-wagon is connected to the rest of the wagons and transported to the line</td>
</tr>
<tr>
<td>13</td>
<td>0,15</td>
<td>-</td>
<td>Empty pallets are highlighted for the pallet-trucks to be able to spot and replace them</td>
</tr>
<tr>
<td>14</td>
<td>?</td>
<td>-</td>
<td>A pallet-truck circles around the material handling areas and visually inspects pallets.</td>
</tr>
<tr>
<td>15</td>
<td>0,5</td>
<td>-</td>
<td>If urgent, a pallet-truck is called in via radio to replace a pallet</td>
</tr>
<tr>
<td>16</td>
<td>0,3</td>
<td>-</td>
<td>Pallet-truck replaces and orders a pallet. The pallet is then removed from the inventory balance</td>
</tr>
</tbody>
</table>

Legend:

- Operation
- Transport
- Inspection
- Delay
- Storage

<table>
<thead>
<tr>
<th>Totals</th>
<th># of steps</th>
<th>10</th>
<th>3</th>
<th>2</th>
<th>0</th>
<th>2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time (min)</td>
<td>4.75</td>
<td>2.0</td>
<td>0.5</td>
<td>-</td>
<td>?</td>
<td></td>
</tr>
<tr>
<td>Distance (meters)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>VA time (min)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

Figure 10 - Current State Flow Process Chart
The FPC above (figure 11) was created with collected data from DE’s material handling platforms and the LC. As can be seen above, some of the numbers were not attainable or they were somehow either not relevant or simply too random to calculate, as the time varied greatly. Albeit some of the operation times are missing, when one is looking at the FPC you can see the different actions that are currently being performed on the pallets and what they contribute. Now, depending on what type of implementation is chosen for achieving full inventory control, some of the operations and other action-types are possible to remove from the process, thus making it faster, more effective and works toward 7+1 wastes (Likert, 2004).

Unfortunately, as not all the times were able to be gathered the data is not complete. However, the majority of the steps are operations (something being performed, e.g. scanning a pallet) with the second most common step being transportation. After that, inspections and storage share the third place. The storage time is difficult to calculate as the time heavily depends on what type of article it is, how many orders have been placed and many other factors. The inspection is similar, as step number 14 is essentially a full-time job where pallet forklifts are driving around and visually inspecting where there’s shortage of supplies in the material handling platforms. In case they miss something, they’re called in via radio. This step would not exist at all with full inventory control as the pallet forklifts would instead see which platforms specifically need a replenishment of material.

4.1.6 Safety Stock

SEA is working with JIT in their production facility, meaning they wish to have only what they always need in their platforms and production lines. However, as mentioned in the previous chapter, there always needs to be a safety stock available in order to minimize and prevent stops in production due to shortage of material. Currently, SEA makes sure to always have enough material to be able to continue consuming for at least two hours in case of a fault in replenishment or reordering.

4.1.7 Replenishing Stock

The replenishment of articles at SEA revolves around the number of pallets or boxes currently stored in their consumption location. All pallets and boxes have Q-numbers which stand for quantity numbers, and this is a form of a Kanban system that’s used to indicate when articles must be replenished. Every box and pallet at SEA has a specific Q-number that displays the number of pallets or boxes that should be stored in the inventory. If the number of boxes or pallets in the inventory is below the displayed Q-number, the forklift driver needs to make an order for a new box or pallet of articles. The Q-numbers for the articles are given based on their consumption levels. The number of articles in their inventory must match the speed of the engine assembly line. If there would be an insufficient number of articles in the inventory at some point it would lead to a stop in the assembly line which SEA strictly want to avoid. As a result of this, some pallets have Q-numbers of 3 and some have Q-numbers of 2. Since SEA don’t have inventory control to the
point where they know how many articles are in their inventory in real-time, they can’t make orders based on how many articles have been consumed from a pallet or a box.

4.1.8 **Box Supply Flow**

**Replenishment System for Boxes**

Box articles at Scania Engine Assembly flow through 2 buildings that are connected to each other. The supplier of box articles is a building called Logistics Centre. The Logistics centre receive orders from DE which is the building where the Engines are assembled. The process of ordering and delivering box articles begins at DE whenever a forklift driver sends an order for a box with articles using a HC-scanner which is a type of barcode scanner. The driver makes orders based on the quantity level of boxes that are currently placed in the storage area either at one of the picking stations or at Line where the engines are assembled. The quantity level is a number that displays the number of boxes that should always be available in the storage. Whenever one box with articles is emptied, the worker who emptied the box attaches a small sticky note to the article ID. The sticky note is an indication of that a new order needs to be made for the emptied box of articles. The forklift driver is the person who’s responsible for sending orders for new box articles, and when a sticky note is spotted the driver places an order for that same article and removes the sticky note. Afterwards the driver attaches a new sticky note with a different colour indicating that an order for the article has been sent.

**Box Management at the Logistics Centre**

The orders at Scania Engine Assembly are managed through a database called SIMAS. The forklifts at the Logistics Centre have computers/displays connected to them which enable the drivers to see placed orders on their computer screens. The orders displayed on their computers are called picking lists. The picking lists display where the articles are supposed to be delivered as well as what articles are included in the order. The orders are categorized by their final destinations, meaning that all the articles included in one order will be delivered to the same destination. The orders at the Logistics centre are all managed according to FIFO, hence meaning that the order which is placed first will be managed first. The forklift driver works accordingly and manages the order which is placed at the top of the display first. The driver accepts the order through the computer and the system registers that the order i is being managed. The forklift driver then proceeds to attach a waggon to the forklift where the boxes of articles are placed afterwards. The waggon that is used to deliver boxes from the Logistics centre to DE each have a destination name displayed at the top of the waggon. The driver chooses the waggon depending on the end destination of the ordered articles, the destination needs to be the same for the waggon and the articles. After the waggon has been attached, it is driven to the location where the boxes with articles are held in the storage. The location with the specified articles is displayed in the picking list. The driver then proceeds to pick boxes according to the picking list. When a box is picked the box is scanned with a HC-scanner and the address code on the shelf is scanned to in order to make sure that the correct articles have been picked. The driver repeats this process until all the ordered
articles have been picked. The articles are then driven from the Logistics centre to a sorting area at DE.

**BOX MANAGEMENT AT DE**

The waggon is dropped off at the sorting area and it is later picked up by a forklift from DE. The forklift from DE delivers the articles from the waggon according to their destinations. The articles are either driven to the picking station or to the Line assembly depending on the destination displayed at the top of the waggon. The forklift driver places the boxes at their specified destinations in the storage and takes out any empty boxes in the storage, the driver proceeds to put the empty boxes on the waggon. The driver also makes orders continuously whenever any sticky notes are spotted along the way of the delivery of articles. When the articles have been delivered, the waggon is left with empty boxes and the waggon is driven back to the sorting area at DE where the driver proceeds to drop it off. A forklift from the Logistics Centre then picks the waggon up and delivers it back to the Logistics Centre. This process is continuously looping throughout the working hours of the plant.

4.1.9 **PALLET SUPPLY FLOW**

**PALLET MANAGEMENT IN LC**

Although the supply flow for pallets is somewhat alike to the supply flow for boxes, there’s a few differences that makes it necessary to describe and handle the two flows separately. The flow for pallets, taking into consideration our delimitation for the thesis project, starts in the storage racks in LC. As soon as DE orders a pallet from the platform position, a signal is sent to SIMAS, who in turn takes this information and creates an order for the scanned pallet in LC. The order is sorted according to the following:

- The amount of pallet collars.
- The weight of the pallet.
- The type of engine the articles in the pallet is dedicated to.

When the sorting is completed in SIMAS, the signal is then sent to an engine-specific printer in LC. As written above, depending on which engine the articles are designed for, the package flags will be printed by a dedicated printer in a specific location. The package flags consist of information that can be useful for the material handler, such as the address for the pallet, the weight, the number of collars and more. Since LC has no system in place that automatically sorts the printed package flags, this needs to be manually processed by someone. They are then placed into a pocket where they are picked up by the material handlers whom will start to pick the pallets. The pallets are located, picked from their locations, and placed in a so called MAFFI-wagon. When they’ve finished their batch of pallets, they place the package flags on top of the pallets on the MAFFI-wagon. These package flags will be utilized by another forklift driver whose job is to make sure that the correct pallets have been placed on the MAFFI-wagon. This is done by scanning the original package flags (placed by the supplier) and then scanning Scania’s custom package flags.
As this process is conducted by a so-called dummy-scanner, no signals are sent to SIMAS or any other Scania system, meaning the scan is “off-the-grid”. If the information checks out, there’s two possible outcomes for the pallet:

- If the pallets are marked D16 (V8 engines), the wagon is placed in a “handover-area” inside of LC, where they are then picked up by a forklift from DE.
- In any other scenario, the wagon is forwarded to a sorting-area for incoming goods at DE. Here, they are sorted according to their destination.

Any deviations in pallets or articles in LC are handled by someone called an Andon, who is responsible for the material control in the LC storage.

**Pallet Management in DE**

When the pallet has arrived at the sorting area in DE, pallet forklifts from DE start emptying the pallets from the MAFFI-wagon and put them down in an unloading platform. From there, another pallet forklift starts sorting them according to the destination of the pallet; the platform address. There’re several “pockets” depending on where the destination of the pallet is. Afterwards, it is picked up by yet another pallet forklift, which makes sure the pallets are transported to their correct corresponding positions. Depending on its platform address, some of the pallets are sent to the material handling areas where they are put into storage level while other pallets are sent directly to line, where they immediately are consumed.

When the pallet has been placed in the storage level of DE, it remains there until the material handlers run out of stock in the consumption level. When this happens a pallet forklift, whose sole intent is to make sure to replenish the consumption level, reorders and replenishes the articles. The pallet forklift driver does this by first scanning the pallet address and then the platform address. The first scan triggers an “pending order”. The order is pending until it gets verification that the inventory balance is reduced (see figure 11 for how inventory balance deregistration is done). This is done with the second scan, where it sends the system a signal that a pallet has been picked down to consumption level. After scanning both bar codes, the forklift driver lowers down a pallet from storage level to consumption level. A new order for a pallet has now been sent to LC and is going to be prepared to be transported to DE.
In the consumption level (which is the level of the storage racking where the material handlers pick the articles that are to be sent in “kits” to the line) the items are no longer sent as pallets but instead as individual items or in “batches”. The material handlers have lists that are printed out by a system called PICK (see 4.1.9.2) that specifies what type of articles and their amount they need to pick for each kit. The material handlers are working with 6 kits simultaneously (depending on which material handling area they’re working in). This means they handle 6 PICK lists. Each of these lists are placed in a separate pocket on so-called kit-wagons. Once the material handlers have finished picking all the articles, tallied and double-checked them and stamped them for confirmation that everything has been correctly done, the wagon is sent towards the engine assembly line. Before the articles reach their destination however, they’re checked in a QC (Quality Control) position to make sure there is no damage or deviation present in the kits. SEA wishes to, in the future, have a system that deducts articles once they’ve been picked from the pallets instead of immediately when the pallets have been picked down to consumption level (see figure 12).

4.1.10 ERP SYSTEMS

Scania Engine Assembly CV use multiple IT-systems that have differing functions, these IT-systems work together in order to have an overall system that keeps track of their inventories, orders, picking-lists and more which will be covered in the current chapter.

SIMAS

SIMAS is an abbreviation for Scania International Material Administration System which is a system that Scania are currently using to handle their internal material. SIMAS is a subsystem to MONA which is the system that handles material control, material planning and orders for material. SIMAS can be used to manage orders, print lists and labels, send material transactions and much more. However not every Scania facility uses SIMAS to its full potential as some facilities choose to implement only some of its functions into use. For instance, SEA use SIMAS to manage the inventory balance and for a few other purposes which aren’t in the scope of this study, while other facilities might use more of SIMAS’ built in functionality. SIMAS works together with the other subsystems in MONA as well as a few external systems. SIMAS could replace a few of the other systems as it contains a wide range of functions, however SEA has
chosen not to do so as they prefer some of the benefits given from using other systems as well. For instance, SEA use a system called PICK in order to print lists and labels for the material handlers, SEA views this system as more user friendly than SIMAS. The combination of systems complicates the chances of getting full inventory control as some of the systems don’t directly communicate with each other. SIMAS and PICK are a good example of this, SIMAS manages the inventory balance and PICK manages the picking lists at the picking stations but they can’t communicate with each other. In order to make them communicate with each other and share information it would be necessary to implement a translator or find ways to solve the problem.

**PICK**

PICK is an abbreviation for Parts picking system and it’s one of many systems currently in use at SEA. PICK is a system that’s used to print picking lists for the picking stations at SEA. PICK works together with MONA Assembly which is a subsystem of MONA. MONA Assembly has the working orders stored in its system which PICK retrieves and then prints for the material handlers to pick. PICK and MONA Assembly also don’t communicate but they have a translator between them that allows for PICK to retrieve the information that’s necessary in order to make the correct document prints. The picking stations can be configured with visual picking which consists of a screen that displays what material needs to be picked. They can also be configured with a printer that prints out reports with the goods to be picked. SEA use printers at the picking stations and the material handlers use the printed reports to pick the goods which are then delivered to the production line.

**EBBA**

EBBA is a new IT-system that SEA is planning on implementing at their factory in the following years. The system is expected to support full inventory control however it remains unclear in what ways this could be achieved and whether SEA can implement the system without making any adjustments to it beforehand. EBBA will not be communicating with MONA and for them to communicate with one another a translator will be needed.

### 4.2 Benchmarking

To be able to properly compare the inventory control system in SEA with other types of systems, we cannot just rely on scientific literature and theories. Therefore, we’ve decided to collect data from another Scania facility in order to be able to perform a form of benchmark on them; compare their performances and capabilities with each other and see what the major differences are and which of the alternatives is the preferable one (depending on what outcome is most desirable). The results will help provide Scania with a sustainable and proper way of implementing full inventory control in their facility.

#### 4.2.1 Scania Production Angers

Scania Production Angers (SPA) was selected as a proper candidate for performing a benchmark and using as a reference for finding suitable solutions for the implementation of full inventory
control in SEA. The production facility was built in 1992 in Angers, France and they have around 670 employees. Their main objective is to take all the different components and parts created by Scania facilities around the world and assembling them into the final product: trucks. Their main customer base is countries in Southern Europe although they do supply globally when the demand exists.

The reason this facility was chosen as a candidate for the benchmarking was because their material handling has a higher level of inventory control than SEA currently has. There are several factors and reasons for this being attainable and these will be presented in this section. Thanks to their inventory control system, SPA is able to lower around 1000 pallets in total from their inventory, lowering tied-up capital and holding costs.

**IT Systems**

Just like in SEA, Scania Production Angers use the SIMAS system for their in-house stock and logistics. They currently exclusively use SIMAS for picking, although SPA has previously tested PICK in their facilities but simply decided to not implement the system. According to Ruet & Vitet (2019), this decision has one important reason: support. Ruet says it has to do with the fact that they have less support presence if they would use the PICK system for picking on their platforms. This is because the system was designed and developed by the Brazilian, meaning they would only have two people from Brazil to support their production line. In contrast, the SIMAS system has six people who can support them. This is according to them, problematic, as they feel two people in support would not be enough. The next step for them is to implement pick to light on their platforms.

SPA had previously tested another type of inventory control system, where they tried having automatic unit supply ordering using something called Mona Conception. When there is a need on the line the order is automatically sent to SIMAS and a pallet is then ordered. However, since MONA is not always precise, this meant there could be some deviations in the order and what MONA needs. Therefore, they do not use this method. SIMAS is currently able to have inventory control for unit supply, but SPA is not utilizing it at this moment.

**Confirmation of Picked Items**

When it comes to confirmation of picked items for deducting balance in the inventory records, SPA uses two different methods in their kit material handling platforms. The first method is done by printing out a material handling list with the help of a computer. After all the items have been picked, the material handler goes back to the computer in order to enter and confirm the picked items. The software, SIMAS, then deducts the picked items from the inventory record. The second method is a bit more efficient: barcode scanning. SPA has implemented barcodes that work as identifiers for different material handling lists. When these barcodes are scanned, it’s a signal to the system that the parts on that specific material handling list now have been picked. They are then deducted from the inventory record. The material handlers cannot continue with the next list until they have confirmed the kit either in the system or by scanning the barcode. A big
improvement of having individual counting of parts by deducing them from the inventory records is that the material handlers don’t need to keep track of which pallets are empty or not, since the system already knows it. Whenever the system sees a pallet reaching the replenishment point it automatically orders a new one, which is a win when it comes to productivity and 7+1 waste.

**Deviation in Material/Stock**

As Axsäter (2015) mentions, one of the more difficult aspects of having a properly updated inventory record is having the people follow the procedures. However, sometimes deviations are out of the control of the production facility and is instead a problem from the suppliers’ side. Nonetheless, it’s something that needs to have preventive measures in order to keep the deviations from damaging the inventory control. SPA sometimes have a problem with suppliers not respecting the quantity inside of the pallet. This creates an issue because they have a fixed quantity inside of the system, meaning the real quantity and the system quantity will differ slightly, causing issues with inventory control. Most of the time SPA does not detect these types of deviations before they start picking, however they do perform comparisons and audits from time to time between the physical balance inside of the pallets and the one presented in the system and updating the records accordingly. SPA says having a random sample tests of pallets from the suppliers as a preventive measure. Team leaders are generally the one who handles and has responsibility to record the deviations.

**Package Traceability**

When it comes to being able to track and trace packages in their facility, SPA says that currently they do not have full knowledge of where the pallets always are. However, they do know that the pallet is currently being transferred and who it has been transferred by. So, in cases where deviation occur with pallets, they know who picked it and between which location it was transferred, making tracking a bit easier.

**Issues and Obstacles**

SPA says even though their inventory control works properly today, they have some obstacles and issues. One of these issues is that they do not currently have full inventory control in all aspects of their picking. An example of this is their sequence picking, which currently does not have inventory control the same way their kit picking does. SIMAS has a lot of functions and possibilities that are currently not used, and they hope to expand on its functionality in the future.

4.3 **Case Studies**

The following case study was chosen as an example of how barcode scanning can help with improving the inventory control within a company. The case study was found online whilst searching for scientific reports on how barcode scanning can improve inventory control and this case study was included in this report since it further validates that barcode scanning can be used for this purpose.
4.3.1 **Bjurab Sweden AB**

Bjurab Sweden AB is a company located in the Swedish city of Halmstad. The company produces projector screens and they produce approximately 80,000 screens a year. Bjurab AB works according to the lean principles and their production is pull-based. The company struggled with the management of material and information connected to it. Bjurab felt that the articles shown in their system didn’t represent the actual number of articles that were in their inventory in real time. As a result, this led to various problems such as ordering material too late and wasting time on searching for material in the factory as they didn’t track the material very well. One solution that was proposed for Bjurab was to implement a barcode system as it would allow them to have a better inventory control and use that knowledge to order new material more efficiently and accurately. This would help them with problems such as ordering an abundance of materials and storing expensive material in their inventory for long periods of time (Nihlén & Uddstrand, 2007).
Chapter 5: Analysis

This chapter will manage the analysis methods performed and compare the theoretical framework with the empirical data collected. The suggestions for the proposals of the thesis, different analysis methods and conclusions drawn from a fictional case will be discussed in this chapter.

5.1 Analysis of Suggestions for Improvement of Inventory Control

This part of the study will present and analyse the multiple possibilities that were found while conducting the study. The theoretical framework and the empirical findings are the two key factors that were used in order to find possibilities for SEA to improve their inventory control. The possibilities will be analysed in this chapter of the study with the use of various analytical methods such as, SWOT-analysis, a Pugh matrix analysis and cost-benefit analysis. An analysis of the current situation at SEA and the theoretical framework will also be made. Suggestions for SEA and answers to the research questions will be made in the next chapter and they will be based on the analysis in the current chapter.

5.1.1 First Proposal: Building on Existing Technology

Background

This proposal would consist of a barcode system that would be used for scanning material, pallets and boxes. The barcode system would be used mainly to improve the inventory control. 100% inventory control is defined as having complete knowledge about the number of articles in each pallet or box and knowing the location of the material, both in real time. The barcode system would therefore focus on improving these 2 factors in a way that’s reasonable considering the current situation at SEA. Since this technology already exists and is currently used for ordering material at SEA, the experience and familiarity with the use of it is higher than for technologies that haven’t been used before. An example of this is the benchmark used from Scania at Angers. Since they use barcodes and barcode scanners to keep track of articles in their inventory, their experiences can be used as an example of a real-life scenario where the technology is used which is a good opportunity to see how the technology performs and what results it can achieve. According to (Ruet & Vitet, 2019) the implementation of barcode scanners enabled the factory in Angers to lower their inventory balance with 1000 pallets which was beneficial since they freed up tied capital and lowered holding costs. Both (Oskarsson, et al., 2013) and (Axsäter, 2015) discuss how freeing-up tied up capital and holding costs can be beneficial as the money that’s freed-up can be used for other purposes which opens up new opportunities.

Implementation

The implementation of the barcode system can be done in various ways, the method chosen in this study was chosen in the light of the scope for this study, the current situation at SEA and the time available to conduct the study. There would be 3 instances of scanning in total between LC and
In order to keep track of material there are 2 instances of scanning, one which takes place at LC and one at DE. The purpose of the first scan is to document the departure of ordered material from LC to DE in the Enterprise Resource Planning (ERP) system whilst the second scan is meant to document the arrival of the material. The first scan would be made by the person that picks the ordered material at LC. Before the person picks the material from its place in the inventory, the person is supposed to scan the box or pallet in order to register that the ordered material has been picked and that it will be delivered to DE. The next scan would take place once a box or pallet is placed in the inventory at DE and scan would be made by the person who placed the material in the inventory. The third and final instance of scanning would take place every time when a material handler is finished with picking materials for an order at the picking stations. There will be a barcode printed on the picking lists that are currently being used at DE and once the material handler has picked everything according to the picking list, the handler will scan the barcode using a finger-scanner which will register that the material has been picked. This would cause the number of materials used for that pick to be deducted from the balance in the ERP-system.

5.1.2 Second Proposal: The Digital Approach

In contrast to the first proposal, which would be an attempt to build the inventory control on top of the already existing systems and technologies, the second proposal for closing the gap on inventory control is more directed toward new technology and a different system-approach. The digital approach would consist of technologies and equipment such as touch-screen tablets and RFID-tags. The tablets would replace every “administrative” task that the material handler currently performs such as collecting the necessary paperwork, double-checking every individual piece of paper and stamping as a confirmation that everything has been picked correctly whilst the RFID-tags would help in adding a layer of pallet and box traceability to the system. Delers et al. (2015) discuss how it’s important for companies to not fall behind in a competitive aspect which is something that the digital approach could prevent since the second proposal consists of innovative technology.

5.2 SWOT-Analysis

A SWOT-Analysis will be conducted in order to analyse strengths, weaknesses, opportunities and threats regarding the two proposals. After each one of these have been analysed, the analysis will be used as a basis for the suggestions to Scania that will be presented in chapter 6 of the study. The SWOT-analysis will be divided into four parts, one part for each one of the factors that will be analysed.

5.2.1 Strengths Proposal 1

Barcode scanning is efficient as it sends information to ERP-systems with a single scan. If a barcode is printed on a paper sheet, that paper can be scanned in order to withdraw articles from the balance. SIMAS also supports the use of barcode scanners which means that Scania don’t have to develop or buy new software in order to introduce barcode scanning. Scania in Angers currently use barcode scanning with SIMAS-pick which could also be implemented at SEA in Södertälje.
Barcode scanning is ergonomic in the sense that there are some barcode scanners which don’t even require contact as they have a laser that scans the code (Bowersox, et al., 2012). Even if the scanner does require contact, the process is quick, and the information is sent as soon as the scanner touches the code. SEA have expressed that ergonomics and user friendliness is of importance at their factory and barcode scanning is fulfilling in that sense (Rydberg, 2019). Also looking at the 7+1 wastes, one of the wastes that (Liker, 2004) talks about is unnecessary movement. Barcode scanning does not require any movements that are unnecessary or time demanding. Barcode scanning is commonly used in other factories as mentioned earlier which in this study is seen as a strength. The reason why it’s seen as a strength is because others use it and they’ve proven that it works well without much error, one example of this is Scania in Angers (Ruet & Vitet, 2019).

5.2.2 Strengths Proposal 2

One of the strengths of the second proposal is the technological advantage it has over barcodes and barcode scanners. Tablets can be used for several different job assignments and can be given multiple functions. The possibility of expanding the use-case of the different technologies in the proposal gives it a clear strength in contrast to using outdated tech. Using tablets would also mean replacing relevant paperwork wherever the equipment is supplied. This has the benefit of making SEA more environmentally friendly, but it would also remove costs from purchasing paper and ink, maintaining printers and would also open the possibility of redirecting work-hours from the removed paperwork in the material handling platform to other value-adding activities which could instead benefit the company and get a step further into the development of 7+1 wastes (Liker, 2004).

Assuming the tablets are going to be stationary, the ergonomics will also be a strength of this proposal. A click on the touch screen of the tablet is less physically demanding than picking up papers, stamping them, folding them and placing them. Walking around with a scanner in your pocket or having to reach for one every time you need to make a confirmation of picked items is less ergonomic as well as less user-friendly than simply pressing a confirmation button. The fact that less actions are needed also improves time-efficiency for the material handlers. Because replenishments are going to be more efficient thanks to a more accurate stock balance, aspects of lean such as JIT and Kanban would also improve (Liker, 2004).

5.2.3 Weaknesses Proposal 1

One of the weaknesses of barcode scanning is that it requires a person to perform the scanning itself meaning that it can’t work automatically. In order to keep a high traceability while using barcode scanning, it would be necessary to implement multiple instances of scanning which would be a waste of both time and labour cost. Another reason why this is a weakness is because it’s impossible to achieve 100% traceability since it’s impossible to trace items in real time using a barcode scanner. One of the weaknesses with the first proposal is that the barcodes will be printed on paper sheets which isn’t very environmental since large quantities of paper are printed at the picking stations at SEA today. The paper sheets aren’t a necessity however and tablets could be
used instead of paper sheets. Another weakness with barcode scanning is that for the barcodes to work with SIMAS, SEA will have to find a way to either make SIMAS and PICK communicate with each other or to replace PICK with SIMAS-pick for example or with another IT-system that communicates with SIMAS. The communication between SIMAS and the IT-system used at the picking station is important as SIMAS manages inventory balance at SEA and for SIMAS to deduct articles from the balance, information will have to be sent one way or another to SIMAS from whichever IT-system is used at the picking stations. The process of finding a way to make systems compatible with one another can be time consuming and expensive, the same would be needed if SEA were to replace PICK with a new IT-system.

5.2.4 Weaknesses Proposal 2

A clear weakness in the second proposal is the fact that new technology takes time to implement, whether it be a system, a piece of new equipment or something else. This means that a lot of time and money need to put toward training not only the personnel who are going to be utilizing the technology but also the ones who are supposed to keep maintenance over it and support it.

Similar to the first proposal, a bridge either needs to be built between PICK and SIMAS by either having a “translator” as MA and PICK has, or simply by removing PICK altogether and solely relying on SIMAS for the picking (Azzo, 2019). Without this bridge of communication, there cannot be a deduction of the stock balance using only the material lists supplied by MONA Assembly (Stokic, 2019).

The second proposal has more upsides than downsides when it comes to functionality and possibilities but alas it comes with a price of high costs in both equipment and training. Due to this, the stakeholders need to consider whether it is worthwhile to invest in this proposal with the help of a capital budget. The first proposal can reach similar results in a cheaper manner, although they might not be as optimal and functional as the second proposal is and it is definitely not as expandable as the second proposal.

5.2.5 Opportunities Proposal 1

One of the biggest opportunities with the implementation of barcode scanning is the possibility to have automatic replenishment. It would be beneficial for SEA to have this since it would save a lot of time and labour cost. Another opportunity with barcode scanning is that SIMAS already supports barcodes (Ruet & Vitet, 2019), meaning that SEA don’t have to do any development or purchases in order to have an IT-system that supports barcodes. SEA can also look further into how Scania in Angers have done in order to implement this and gain more knowledge which could be beneficial for SEA. SEA would be able to save money and time through the implementation of barcodes. If barcodes existed there would be no need for the forklift drivers that currently work with looking for orders at the inventory in the picking stations. Implementing barcode scanning for the purpose of having better inventory control would lead SEA in the direction of industry 4.0 which can be a good opportunity for SEA to gain experience and knowledge regarding industry 4.0 and implementation of technology together with lean.
5.2.6 Opportunities Proposal 2

Like the first proposal, the digital approach would create several opportunities. Some of these include but are not restricted to: better stock balance accuracy, possibility of having automatic replenishment, increasing time-efficiency of workers, reducing work-hours for certain assignments, removing necessity of some assignments such as the pallet forklift driving around looking for empty pallets and if executed properly full traceability of pallets and boxes is possible. All these possible improvements develop SEA’s lean further toward the ideal and closes gaps on inventory control (Liker, 2004).

5.2.7 Threats Proposal 1

The threats that exist with implementing barcode scanning is that it might be difficult to make SIMAS co-operate with other systems. SEA could do the same thing as Scania in Angers have done but they might lose out on some of the good aspects of their current IT-system at the picking stations called PICK. Barcode scanning has been around on the market for many years and ever since its’ creation, other products have been created that are more cutting edge than barcodes since they allow for more automation. SEA might not be very competitive compared to some other companies if they choose to implement barcode scanners even though it would increase their inventory control. If SEA decide to use barcode scanners and manage their inventories according to the new way of material deduction in SIMAS, they might end up running a bigger risk of production stop due to insufficient numbers of articles being in their factory. If the suppliers send insufficient amounts of articles to SEA, SEA might need to stop their production if they manage their stocks in a way that leaves them without safety stocks. SEA want to have a smaller amount of tied up capital than currently and the implementation of proposal 1 will make this possible, however doing so might increase the chance of having production stops. Their production will be dependent on whether their suppliers send the correct number of articles to them or not. The human factor is also an inevitable threat as it can be one of the reasons errors occur.

5.2.8 Threats Proposal 2

When interviewing Scania Angers (Ruet & Vitet, 2019), it was mentioned that one of the obstacles of trying to achieve full inventory control with methods such as barcode scanning is the human factor. Manually registering and deducting items from the stock balance is a good way of achieving next to real time stock balance, however it has its downsides. The system is fully dependant on whether the material handlers report deviations, if the suppliers have sent the correct number of articles and that nobody is walking around stealing or “borrowing” items from the platforms. This issue will persist even if the proposal with the tablets are implemented instead, unless RFID-tags are used to register/deregister items from the balance as was mentioned earlier. Touch-screen tablets will still need manual input and confirmation, including deviations. For SEA to bypass this issue, a solution for non-discovered deviations needs to exist. This way, even if deviations were to occur that are in fact not registered in the system, the system can find out that items are missing from the boxes and SEA can send inspectors to the platform to further improve stock level.
accuracy. This means that the inspectors they have today are still needed, however they will not need to visit the platforms as frequently, further reducing working-hours in that field, allowing for the possibility of investing those working hours in more value-adding processes (Liker, 2004).

5.3 **Pugh Matrix Analysis**

As a way of easing the selection of proposals for stakeholders, a Pugh Matrix can be used as explained in the methodology chapter. Before creating the matrix, a few important key factors were decided upon, which would be affected depending on which proposal is chosen. As Bailey & Lee (2016) mentions, the “concepts” (or proposals) are not set in stone. The matrix can be used as a visualization tool for locating strengths and weaknesses of a specific concept. When properly used, Bailey & Lee (2016) claims an even better alternative can be produced if the stakeholders wish to. For the purpose of this thesis however, the proposals have been limited to the two already defined.

**Ergonomics**

The ergonomics of the native system compared to the two proposals are not vastly different, however they do vary slightly. The first proposal creates a necessity for the material handler to either carry with themselves a scanner at all times or alternatively have a fixed position for a scanner which they have to walk to in order to finish their lists. This slightly affects the ergonomics of this proposal, as the material handler needs to perform more potential uncomfortable bodily movements that were not there previously. The second proposal however, with the touch-screen tablets, instead removes unnecessary and uncomfortable actions/movements. There will no longer be any fetching and stamping of paper lists. Instead, a fixed touch-screen will be used in order to look over the digital picking list and also to confirm (stamp) the list when they’re done.

**Time-Efficiency**

Similarly, the time-efficiency of the two proposals will vary due to added actions in the first proposal and removed actions in the second proposal. Since there will be added steps in the first proposal, with the scanning of the lists and the packages for traceability, the time-efficiency slightly worsens. The second proposal removes any need for paper. This means fetching paper from the printer, putting them in its designated location, picking them up when needed, sorting them into their respective “pockets” and stamping them when completed will all be removed. Instead, the material handlers will open the list on their touch-screen tablets and simply confirm once when everything is completed. This can be seen in the flow process chart created in chapter 4.

**Replenishment Efficiency**

The current replenishment system at SEA is placed at 50% as they use barcode scanning to make orders which works efficiently. The observations at the factory also revealed that there are specific forklift drivers that drive around the factory looking for boxes or pallets that need to be reordered. SEA currently use sticky notes with two different colours that indicate whether an order needs to
be made or whether it’s already been ordered however this method is only used for ordering boxes. The box forklift driver drives around looking at these sticky notes using them as signals and indicators. The replenishment process for pallets is similar but there’s no usage of sticky notes. Instead the forklift drivers look for pallets that look empty or that have lids placed on them while the pallet is located at ground level. Sometimes the material handlers call the forklift drivers and tell them that there’s an empty pallet in the picking station (Scania, 2019). Both processes could be removed with the use of barcode scanning as the scanning would display a real time number of articles in boxes and pallets. A reordering point can be set for when \( x \) number of articles are left in a box or pallet. This would allow for automatic orders as the system could be set to make new orders automatically when the balance reaches the reordering point. The orders can also be managed manually by someone on a computer who monitors the inventory balances and makes orders when needed. If the replenishment was managed automatically the replenishment efficiency would be at \( 80\% \) as this would be close to a completely automatic procedure with real time balance.

Similarly, working with tablets when picking would increase the performance of replenishment at the material handling platforms. As the stock levels would be more accurate and closer to real-time counting of items using deduction per kit assembled rather than deducing every pallet when it lowers to consumption level. The scanning of barcodes and registering a picking list complete via the tablet is essentially the same when it comes to how the items are counted and thus the tablet has the same performance in this aspect. SEA is currently using a form of Kanban card to replenish their materials (Q-number) (Rydberg, 2019). If the replenishment would be automatic, with the help of counting stock level by individual items, digital automatic Kanban cards based on item quantity instead of pallet quantity could be introduced would improve the efficiency and timing of replenishment, furthering improvements on 7+1 waste (Liker, 2004) and JIT (Ax, 1997).

**Stock Level Accuracy**

The way SEA manages stock levels in the current state is by viewing boxes and pallets with a value that they call Q-numbers. 1 Q-number represents either 1 pallet or 1 box and the articles have Q-numbers assigned to them depending on how fast they are being consumed. SEA treat all articles in the form of Q-numbers meaning that the replenishment and all other instances of material handling happens at a box and pallet level (Scania, 2019). As a result of this they order new material when pallets and boxes are completely emptied. SEA have managed their inventories in such a way that they always have a new box or pallet ready to be consumed after a previous one has been emptied. This type of inventory management creates a necessity for at least 1 pallet or box to be stored in the inventory while the other box or pallet is being consumed. If they implemented barcode scanning at the picking stations, they would have close to real time knowledge regarding the number of materials in pallets and boxes which means that the number of articles for instance in a pallet would be deducted each time an article is consumed. In the current state the deduction happens for the entire box or pallet once it has been consumed. With the bar code scanning the deduction happens closely to real time consumption of articles.
Unless the RFID-tags from the second proposal are used for the purpose of removing items from the total stock balance, the second proposal would have identical performance in this specific area. Because the only difference in how the stock levels is handled is that the deregistration of items is either done via scanning a barcode vs. confirming on the tablet there is no direct performance difference in this part of the proposal. Deregistration of items from the total store balance with RFID-tags could be implemented by inserting tags on expensive or high-volume items. These would pass by a RFID-scanner that can see where the item currently is located. As soon as it passes a desired “digital border”, the items would be removed from the store balance and transferred to any preferred balance. It can also vice versa be added back into the stock if the scanner detects movement of the items back onto the platform.

**USER FRIENDLINESS**

The ability for the material handlers (the users) to quickly adapt to and learn the new systems depends on how they’re executed and implemented into the company. However, assuming that the systems are properly developed and implemented, the first proposal won’t really have any effect on the user’s feelings about system-friendliness, since the only changed step is scanning instead of stamping, which should not have any effect on the material handlers. The second proposal, with its introduction of tablets, will feel somewhat new and unfamiliar at first (especially for current employees). However, when they have adapted to the newly developed system, it’s going to be more friendly than their current ones, as there’s less steps and more visual aid in your picking. This will be especially noticeable for new employees, as they are going to be more familiar and comfortable with the new system due to not having any baggage from the old system.

**JIT**

The aspect of JIT will be affected the same way with the introduction of either proposal, since it’s dependant on how the order and transportation of the items are handled. Having full inventory control and information about the whereabouts of packages and more would give the company better chances of improving their reorder points, replenishment, reduce the number of packages in inventory and more. Also knowing where the packages currently are would help in making sure the client (the production line) gets the right number of items in the right time and right place (Ax, 1997).

**7+1 WASTES**

The first proposal might result in time-demanding events appearing as a result of the implementation. An example of this is the time it takes to perform a barcode scan. Due to this it got a (-) whereas proposal two got a (+). The second proposal is more autonomous and less time demanding which means that the 7+1 wastes would be lower if the second proposal was implemented.
**Package Traceability**

Item traceability represents how much traceability for instance SEA has over their materials. SEA currently don’t know where any of their pallets or boxes are after an order is made at DE. They only know that it should take approximately 2 hours for the pallets and boxes to arrive to the picking stations at DE. This means that they barely have any traceability at all. However, if they were to add the 2 events of scanning that were mentioned earlier, one when the materials is sent out for delivery to DE and one when they arrive to DE then they would at least have information about the departure and arrival of the items.

What SEA could do to come closer to the ideal traceability accuracy is implementing more scanning stations which would lead to better traceability or use other technologies such as RFID that can automatically scan pallets, boxes or even articles. This would be achievable using the second proposal, where re-usuable RFID-tags would be placed on pallets and possibly higher-value boxes in order to increase traceability and thus increase the total inventory control. Using RFID-tags, SEA would have the possibility to see where the pallet or box is in real-time, without any added stages of scanning which would lead to an increase in working-hours. This proposal is more efficient, however will lead to higher initiation costs for SEA. For the purpose of this thesis project, an assumption will be made that SEA would only put RFID-tags on their pallets and not their boxes.

**Competitiveness**

SEA haven’t implemented technology to a high extent when it comes to material handling. As mentioned earlier, they don’t use barcode scanning, QR-codes, RFID or tablets as tools for managing inventories and material. They just use one instance of barcode scanning which is when they order new material (Scania, 2019). Scania in Angers on the other hand have implemented barcode scanning as a tool to achieve better inventory control (Ruet & Vitet, 2019). In the case study that was conducted by (Nihlén & Uddstrand, 2007) at Bjurab AB it was also recommended for Bjurab AB to implement barcode scanning in order to improve the inventory control. The case study at Bjurab AB was conducted in 2007 which is 12 years ago meaning that barcode scanning isn’t new or viewed as cutting edge technology today. Bjurab AB had problems with their replenishment and ERP-system which is something that SEA don’t have to the same extent as Bjurab AB had and therefor the two companies aren’t in the same state and situation. SEA have worked a lot with the lean principles such as minimizing the 7+1 wastes, improving the 5S and implementing Kanban but it seems as though lean is reaching its limit as mentioned by (Kolberg & Zühlke, 2015). If SEA were to implement barcode scanners to a higher extent, they would be more competitive with other companies that already use these kinds of tools.

Albeit expanding and building on top of already existing technology can be beneficial and increase competitiveness in the market, it will not have as big of an effect as implementing new and fresh technology would have. Even if competitiveness is a hard metric to measure, it’s logical to think that new technology that increases efficiency, productivity and increase other aspects of
profitability for the company would increase this metric. The idea of using tablets instead of paper and scanning equipment would put SEA’s competitiveness in a slightly higher tier and open doors that were previously not possible, such as the possibility of not only using RFID-tags for tracking but also for scanning/registering in the future. The same goes for RFID-tags, which can not only be used as a way of real-time tracking of items but also as a way of registering unique items when exiting/entering certain areas in a production facility according to (Al-Ani, 2015). The possibilities these technologies bring into the company could be expanded upon in the future.

**RESULTING PUGH’S MATRIX**

When observing the created Pugh matrix (see figure 13), the sum of all negatives and positives is fast seen. As is visible in the matrix, proposal 2 has the advantage of having the most positives of the two proposals. One should not automatically assume this is the best concept however, as it depends on which key factors are important for the stakeholders. For example, as can be seen in the matrix, most of the key factors are better with the second proposal, however it comes with a price. The cost of purchasing the equipment and preparing the necessary training (for IT and workers) is higher. The strengths and weaknesses of each proposal has been collected partly from section 5.2 and partly from section 5.3, while other key factors have been logically set (e.g. such as 7+1 wastes, because of potentially reduced/redistributed work-time). The costs will be further detailed in the next section.

5.4 **COST-BENEFIT ANALYSIS**

The CBA will treat a semi-fictional case. A fictious case will be constructed and a CBA will be conducted for the two proposals within this case. Some of the costs and benefits will be shared between both proposals, meaning they will both have some of the same costs and benefits, independent on which proposal is chosen. The costs/benefits that are not shared will be detailed further in section 5.5.5 and 5.5.6. Note that all these costs and benefits are mostly fictional and will vary depending on the company regarding stock, ABC-analysis of articles and more.
5.4.1 Case Description

A factory has 30 material handlers employed. The factory has approximately 1500 different articles stored in their inventory and the articles are placed in pallets. There are two types of article groups, these are groups A and B. We will assume average spread of articles according to ABC-analysis (except for a C-class, which will instead be a part of the B-class). Articles in the A-group consists of mid-value, high-volume consumption articles, while the B-group articles consist of high-value, low-volume consumption articles. Group A makes out 80% of the total article count, while the B-group is 20% of the total. Group A pallets stand for around 30% of the total value while Group B pallets stand for around 70% of the value, see figure 14.

All the A-group articles have a safety stock of 1 pallet and a Q-number of 3 pallets, meaning that there should always be 3 pallets of that article present in the inventory, if there are less than 3 pallets in the inventory, an order is made for a new pallet. The B-group has a safety stock of 1 pallet and a Q-number of 1. The lead-time for all the pallets to arrive to the inventory at the material handling platform from the point the order is made is around 2 hours. The A-group pallets have an average consumption time of 2 hours and there are around 100 articles per pallet, while the B-group pallets have an average consumption time of 2 weeks and there are around 20 items per pallet. The purchase price for Group A pallets are 800 SEK, while Group B pallets land around 11200 SEK.

There are three workers that drive around in forklifts and place orders wherever they see that there is a lack of pallets for an article. The factory opens at 6 am and closes at 12 am meaning that it’s open for a total of 18 hours a day. There are 2-shifts for the workers, the first shift is a nine-hour shift from 6 am to 3 pm. The second shift is a 9-hour shift from 3 pm to 12 am.

For each pick at the picking station the material handlers have 5 sheets

<table>
<thead>
<tr>
<th>Table 6</th>
</tr>
</thead>
<tbody>
<tr>
<td>* = mean values</td>
</tr>
<tr>
<td>Total pallet count</td>
</tr>
<tr>
<td>Percentage of value</td>
</tr>
<tr>
<td>Percentage of articles</td>
</tr>
</tbody>
</table>
The system that manages the balance for the articles and the system used for picking don’t communicate with one another, making deduction from the inventory balance directly between the systems impossible and for whichever proposal that is decided to be implemented, this problem would have to be resolved.

5.4.2 Method description

The purpose of the fictive case is to show how a company could be affected by the implementation of the proposals. The theoretical framework and the empirical findings suggested that the implementation of both proposals could allow the company to keep fewer pallets with items stored in their inventory, this was found from the interview with (Ruet & Vitet, 2019) and from the study by (Bowersox, et al., 2012). This would furthermore lead to a release of tied-up capital, lowered holding costs and freed up working hours. The implementation of the proposals could also lead to new costs appearing such as the implementation of a new IT-system, new time-consuming moments that would be required as a result of the implementation, equipment costs and maintenance costs. All the mentioned parameters were taken into consideration when constructing the fictive case and it was of interest to find out whether the results of the implementation would lead up to the same results as suggested by the empirical findings and the theoretical framework. The numbers in the case are fictive, they’re however inspired by real numbers from a company in order to keep the fictitious case relevant in real life scenarios. The calculations in this chapter were made with consideration to formulas from the theoretical framework and with consideration of the empirical findings.

5.4.3 Reordering point

<table>
<thead>
<tr>
<th></th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>SS</strong></td>
<td>100 items</td>
<td>0,25 items</td>
</tr>
<tr>
<td><strong>D&lt;sub&gt;t&lt;/sub&gt;</strong></td>
<td>50 items (per hour)</td>
<td>0,125 items (per hour)</td>
</tr>
<tr>
<td><strong>LT&lt;sub&gt;t&lt;/sub&gt;</strong></td>
<td>2 hours</td>
<td>2 hours</td>
</tr>
</tbody>
</table>

The first thing that was analysed and calculated was the possibility of lowering the inventory levels.

\[
OP = SS + D_t \times LT_t
\]

This formula was used in order to find a suitable reorder point for the current situation at the company. For the group A articles, the calculations looked like this:
Group A articles: \( OP = 100 + 50 \times 2 = 200 \)

This means that a new order should be made whenever the inventory balance is at 200 items or lower for the group A articles. In the current state of the company, the day starts off with 3 pallets in the inventory since the Q-number is 3. One of the 3 pallets is lowered to the consumption level according to FIFO and the inventory balance is deducted with the quantity of items stored in that pallet which is 100 items in this case. Due to this deduction, the balance shows that there are only 200 items at the picking station which means that an order for a new pallet should be placed. The problem however is that there are 300 items at the picking station at the time the order is placed. If the company improved their inventory control to the point where they know the exact balance of the items in the pallet at consumption level, they wouldn’t need to deduct the total number of articles in that pallet in an instance, they could deduct the items one by one as they’re picked. This is something that both proposals would support meaning that if the company was to implement either one of the proposals, they would have the possibility to wait for the entire pallet at consumption level to be emptied before placing an order for a new pallet. This would make the time of the order placement correct as the order would be placed when there are only 200 items at the picking station and not when there are 300 items which is how it’s done in the current state. This would result in the inventory having 1 pallet less stored in it than in the current state meaning that the Q-number could be set to two instead of three if either one of the proposals were to be implemented. This would also lead to lowered holding costs and a reduction in tied-up capital which will be presented further ahead in this chapter.

The calculations for group B pallets looked like this:

Group B articles: \( OP = 0,25 + 0,125 \times 2 = 0,5 \)

The calculation for the group B articles is faulty since the demand for them is low, making the calculations rather obsolete. The reorder-point, according to the theoretical calculation, is 0,5, which isn’t practically possible. Since the consumption for the group B articles is 2 per day, making it one every 8 hours, one can assume that (with a lead-time of 2 hours) a new order can be placed when the last item has been picked. This is theoretically possible, however due to safety reasons and making sure that the line won’t have issues supplying items, we will leave this number at 1. This will in turn reduce the number of pallets in the inventory for all group B articles by one pallet.

### 5.4.4 Release of Tied Up Capital

To be able to calculate the tied-up capital that can be freed thanks to inventory control, one first needs to make a few assumptions. An assumption can be made that high-volume articles won’t be affected too much when it comes to tied up capital as the pallets are almost flowing at a constant rate, meaning they need to be re-ordered and replenished continuously. Instead, the low-volume and high-value items are of significance for this type of calculation. This is because those pallets, that are just sitting by for several weeks, are just a waste of capital that could be invested in something else that can be more beneficial for the company. Tied-up capital (or restricted equity as some may call it) also makes the company lose money simply because of the interest. The
calculations and results will be the same for both proposals since they will both yield the same results and have the same benefits regarding the release of tied up capital.

**Calculations for the Release of Tied Up Capital**

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total pallet value (group A)</td>
<td>$1200 \times 3 \times 800 = 2880\ tSEK$</td>
</tr>
<tr>
<td>Total pallet value (group B)</td>
<td>$300 \times 2 \times 11200 = 6720\ tSEK$</td>
</tr>
<tr>
<td>Total inventory value</td>
<td>$2880 + 6720 = 9600\ tSEK$</td>
</tr>
<tr>
<td>Internal rate of return</td>
<td>15%</td>
</tr>
</tbody>
</table>

The total inventory value is an assumption made for the case description. The value for group A & B pallets is calculated by multiplying the total inventory value with the value-percentages from table 7.

In order to calculate the cost saved from reducing the tied-up capital in inventory, the following formula is going to be utilized (values obtained from table 7 & 9):

\[
(SS_c \times \bar{v} - SS_n \times \bar{v}) \times IRR
\]

\[
(1200 \times 3 \times 800 \times 1200 \times 2 \times 800) \times 0.15 + (300 \times 1 \times 11200 \times 300 \times 0 \times 11200) \times 0.15
\]

\[144\ tSEK + 504\ tSEK = 648\ tSEK\]

### 5.4.5 Reduction of Holding Costs

Calculations that were made earlier in the study under the headline 1.1.3 showed how the implementation of both proposals could reduce each article group with one pallet per article. The holding cost will therefore be reduced for one pallet per article for both article groups and the calculations for this will be presented below. The holding cost for one square meter is 400 SEK/month. Three pallets from the group A articles can fit in the space of one square meter whilst only one pallet from the B group articles can fit in the same space.

<table>
<thead>
<tr>
<th>Description</th>
<th>Group A</th>
<th>Group B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holding cost per pallet a month</td>
<td>$\frac{400}{3} = 133.33\ SEK$</td>
<td>400\ SEK</td>
</tr>
<tr>
<td>Holding cost for an entire article group per year</td>
<td>$133.33 \times 12 \times 1200 = 1920\ tSEK$</td>
<td>$400 \times 12 \times 300 = 1440\ tSEK$</td>
</tr>
</tbody>
</table>

### 5.4.6 IT/System Costs Calculation

There will be costs in order to change the picking system or in order to implement a translator that enables the two systems to communicate and it might be costly. This however is something that
couldn’t be estimated with regards to the time frame of the study. This will be further discussed in the final section of this chapter.

Worth noting however is that if there is, as explained in the empirical findings, a gap in the knowledge regarding certain IT systems that are vital (and already present in the company) for inventory control to properly be implemented, consultants need to be hired. These roles can either be filled by in-house employees or consultants from outside of the company may be hired in. If this is the case, this is also a cost that would show up in conjunction with the investment.

Also, in case there needs to be certain developments or new implementations of IT-systems, this needs to be further researched on. Later in this section, the maximum initial cost will be discussed, and with it the potential of allocating resources to certain parts of the project, such as IT-development.

These numbers are all assumptions, except the average pay for IT-consultants.

Table 10

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of consultants</td>
<td>2</td>
</tr>
<tr>
<td>Average pay (IT consultant)</td>
<td>36 tSEK (Lönestatistik.se, 2018)</td>
</tr>
<tr>
<td>Months needed</td>
<td>3 months</td>
</tr>
</tbody>
</table>

Consultants cost = 2 * 36 tSEK * 3 = 216 tSEK

5.4.7 Redistribution of working hours

One of the benefits that the implementation of proposal 1 would result in is freed up labour time. In the current state there are three workers constantly driving around the picking stations in their forklifts whilst looking for articles that need to be re-ordered. If proposal one was implemented and orders were placed automatically, the workers that currently place orders wouldn’t need to do so anymore. The current working hours of the three workers would be freed up and they could be redistributed, meaning that the workers would be assigned with other jobs within the company. A calculation for the freed up working hours for one year will be made using the numbers in the table below:

Table 12

<table>
<thead>
<tr>
<th>Number of workers ordering pallets</th>
<th>Working hours per day (24 h)</th>
<th>Number of working days per week (7 days)</th>
<th>Number of weeks per month</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 workers</td>
<td>18 h</td>
<td>5 days</td>
<td>4</td>
</tr>
</tbody>
</table>
Working days per year: 5 * 4 * 12 = 240 days

Working hours per year = 240 days * 18 hours * 3 workers = 12 960 h

The results show that the company would free up 12 960 hours per year (for three workers) with the implementation of either of the proposals. These hours could then be redistributed and used for other purposes which could benefit the company more.

5.4.8 Cost-Benefit Analysis: Proposal 1

Costs

The following costs were created based on assumptions and data gathered online. The scanners had an average retail price of 4 tSEK. It’s assumed that it would take 4 tSEK to prepare the scanners for use at the factory. Each material handler will be equipped with a scanner and since there are 30 material handlers in the constructed case, 30 scanners will be implemented.

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost per scanner</td>
<td>4 tSEK</td>
</tr>
<tr>
<td>Cost for installation</td>
<td>4 tSEK</td>
</tr>
<tr>
<td>Material handlers</td>
<td>30</td>
</tr>
</tbody>
</table>

| TABLE 13 |

Equipment cost = 30 * (4 + 4) = 240 tSEK

With all equipment, there comes a cost for preventive- and acute maintenance and repairs. The company’s economics department has suggested an estimated excess 7% maintenance cost (MC) as a percentage over the estimated replacement value (ERV) for the touch-screen tablets and the RFID-readers combined. With this number, the company can estimate how much they will spend annually on different forms of maintenance, repairs and replacements. Since the RFID-labels are not equipment that is suitable for maintenance, it will not be included in the estimation.

Maintenance costs = Total equipment cost * % of MC over ERV

Maintenance costs = 240 tSEK * 0,07 = 16 tSEK

5.4.9 Cost-Benefit Analysis: Proposal 2

For the second proposal, the unique costs and benefits of this package will be discussed and further detailed. Purchasing and preparing equipment such as the touch-screen tablets and RFID-chips, changes in working-hours for the employees and more will be taken into consideration, together with the previously calculated tied-up capital and holding costs.
**Costs**

Purchasing and preparing the necessary touch-screen tablets for the material handling platforms would cost 15 tSEK per tablet. Using the case assumption of 30 material handlers and assuming each material handler needs to have their own touch-screen tablet, the total minimum cost for the purchase of tablets would be:

\[
\text{Cost of purchasing tablets} = 30 \times 15 \text{ tSEK} = 450 \text{ tSEK}
\]

The RFID-tags, in the form of labels, has a recommended retail price of around 7 tSEK for a roll of 5000 RFID-labels. With an all-around total stock level of around 5400 pallets at any given time, and assuming the labels or the pallets will occasionally be damaged, there needs to be a good amount of reserve labels. Purchasing 3 rolls in total should suffice to keep the RFID-tagging going and cover the lead-time for purchasing more rolls in case they run out faster than expected. Since there’s 15 workstations, there needs to be at least 15 RFID readers to track the packages going in and out of the platforms, with a recommended retail price of 15 tSEK for a reader

\[
\text{Cost of purchasing RFID labels} = 3 \times 7 \text{ tSEK} = 21 \text{ tSEK}
\]

\[
\text{Cost of purchasing RFID readers} = 15 \times 15 \text{ tSEK} = 225 \text{ tSEK}
\]

The total cost for all the equipment lands at:

\[
\text{Equipment cost} = 450 \text{ tSEK} + 21 \text{ tSEK} + 225 \text{ tSEK} = 696 \text{ tSEK}
\]

As with proposal 1, the maintenance cost can now be calculated:

\[
\text{Maintenance costs} = \text{Total equipment cost} \times \% \text{ of MC over ERV}
\]

\[
\text{Maintenance costs} = 675 \text{ tSEK} \times 0.07 = 47 \text{ tSEK}
\]

**5.4.9.1 Benefits**

One of the obvious benefits when swapping to a fully digital system is removing the need for paper. This reduces the work-time for the material handlers, as can be seen in the Flow Process Chart in chapter 4. However, since there are no numbers gathered on how long the actuation of the tablets would take in comparison with the papers, these calculations won’t be measured in numbers. Removing the need for paperwork also reduce costs associated with purchasing paper, ink and performing maintenance on printers. The company has estimated that they print out approximately 125 papers per material handling platform a day, totalling to 1875 papers daily in total. Assuming 253 work days a year, this would amount to 474375 printed papers annually. The maintenance for the printers is estimated to be around 230 SEK per year per printer, with a total of 15 printers, costing the company 3450 SEK annually. An estimated retail price for a box of 2500 A4-papers is 195 SEK, making the total price annually for the printers and the papers 40450 SEK.

\[
\text{Cost saved for papers and printers} = 3 \text{ tSEK} + 37 \text{ tSEK} = 40 \text{ tSEK}
\]
5.4.10 **Cost-Benefit Ratio**

The Cost-Benefit ratio will be determined under a two-year period of benefits and costs. This is due to the companies wishes that an investment should have a general payback time of around two years, or they won’t attempt to pursue it. To determine the Cost-Benefit Ratio, the following formula is used:

\[
CB \text{ Ratio} = \frac{Net \text{ benefits}}{Net \text{ costs}}
\]

The costs and benefits from a two-year period will be summarized and injected into the formula:

- \( CB \text{ Ratio for proposal 1} = \frac{8\,016 \, tSEK}{514 \, tSEK} \approx 16:1 \)
- \( CB \text{ Ratio for proposal 2} = \frac{8\,096 \, tSEK}{1\,014 \, tSEK} \approx 8:1 \)

As can be seen from the calculations, both of the investments will have a positive CB ratio, with proposal 1 having the higher ratio.

5.4.11 **Investment Analysis**

The results from the investment calculations from the previous chapters will be presented in the table below. The initial benefits are 0 while the subsequent benefits are the reduction of tied up capital savings, reduction of holding costs and other benefits from the separate proposals. The initial costs are the equipment costs, while the costs for year 1 and 2 are any trailing costs after the IC (see previous calculations for reference):

<table>
<thead>
<tr>
<th>( t )</th>
<th>Benefits Proposal 1</th>
<th>Costs Proposal 1</th>
<th>Cashflow ((C_t)) Proposal 1</th>
<th>Benefits Proposal 2</th>
<th>Costs Proposal 2</th>
<th>Cashflow ((C_t)) Proposal 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>240 tSEK</td>
<td>-240 tSEK</td>
<td>0</td>
<td>696 tSEK</td>
<td>-696 tSEK</td>
</tr>
<tr>
<td>1</td>
<td>4 008 tSEK</td>
<td>256 tSEK</td>
<td>+3 752 tSEK</td>
<td>4 048 tSEK</td>
<td>263 tSEK</td>
<td>+3 785 tSEK</td>
</tr>
<tr>
<td>2</td>
<td>4 008 tSEK</td>
<td>16 tSEK</td>
<td>+3 992 tSEK</td>
<td>4 048 tSEK</td>
<td>47 tSEK</td>
<td>+4 001 tSEK</td>
</tr>
</tbody>
</table>

Now that the benefits and costs have been identified, the investment calculations can go a step further. Firstly, we can calculate the Net Present Value (NPV) with the equation below. The company wishes to have a payback time of maximum two years and the general internal rate of return for the investment is 25%. In order to calculate the maximum initial cost for the investment, the following formula is used (with consideration for the net cashflow):

\[
NPV = -IC + \sum_{t=1}^{n} \frac{C_t}{(1 + IRR)^t}
\]
After the NPV has been calculated, with the assumptions for PBT and IRR we can calculate the maximum number for IC. Setting the NPV as 0 (economic breakpoint), we can calculate the maximum amount of initial costs for the project without the company going into negatives during the two-year PBT.

**PROPOSAL 1**

The NPV is calculated with following equation:

\[
NPV = -240 \text{ tSEK} + \frac{3752 \text{ tSEK}}{(1 + 0.25)^1} + \frac{3992 \text{ tSEK}}{(1 + 0.25)^2} = \\
= -240 \text{ tSEK} + 3001 \text{ tSEK} + 2555 \text{ tSEK} \approx 5316 \text{ tSEK}
\]

Since the NPV has been calculated, the maximum IC can now also be calculated:

\[
0 = -IC + \frac{3752 \text{ tSEK}}{(1 + 0.25)^1} + \frac{3992 \text{ tSEK}}{(1 + 0.25)^2}
\]

\[
IC = 5556 \text{ tSEK}
\]

**PROPOSAL 2**

Firstly, the NPV is calculated using the equation below:

\[
NPV = -696 \text{ tSEK} + \frac{3785 \text{ tSEK}}{(1 + 0.25)^1} + \frac{4001 \text{ tSEK}}{(1 + 0.25)^2} = \\
= -696 \text{ tSEK} + 3028 \text{ tSEK} + 2561 \text{ tSEK} \approx 4893 \text{ tSEK}
\]

Now, the maximum IC can be calculated (this number includes the initial costs for equipment):

\[
0 = -IC + \frac{3785}{(1 + 0.25)^1} + \frac{4001}{(1 + 0.25)^2}
\]

\[
IC = 5589 \text{ tSEK}
\]

**CONCLUSION**

As is concluded from the calculations, the company from the case description is going to be able to invest a total of 5566 tSEK for proposal 1 and 5589 tSEK for proposal 2 without losing money, if the payback period is set to two years with a general IRR. Note that depending on the actual IRR, the values of NPV and IC might vary.
Chapter 6: CONCLUSIONS & RECOMMENDATIONS

The final chapter of this bachelor’s thesis is the conclusion & recommendations section. This chapter will present the authors’ conclusions to the research questions, give a short summary of the research performed, discuss and reflect upon possible sources of errors and give suggestions for future research.

6.1 CONCLUSIONS TO RESEARCH QUESTIONS

The following research questions will be answered with conclusions drawn from the theoretical framework and analysis of the study.

RQ1: What are the necessary steps (changes and alterations) that a production company is required to perform in order to implement full inventory control?

Since the lean principles are starting to reach their limit, the entrance of industry 4.0 is on the rise. Technology is implemented together with existing lean fundamentals to reach higher levels of efficiency in various parts of a production company. Technology is of high value as there is a need for automation and real time accuracy regarding the traceability of items and inventory balances. A company should consider the implementation of technologies such as RFID, barcodes or touch-screen tablets if they want to improve their inventory control. For them to have full inventory control, RFID might be the best option since it’s able to automatically scan items in real time. For a company to implement such technology with successful results, they would need to have IT-systems that are compatible to the point where they fully support these functions. Axsäter (2015) also mentions the importance of having all data available and making sure the risks of error occurring in the data are small. The occurring errors can cause automatic orders to be dysfunctional. The workers that add or reduce the inventory balance must undergo training and instructions to prevent balance errors from occurring (Axsäter, 2015). The author continues to mention how it’s important to find errors fast in order to experience minimal damage from the errors that do occur.

RQ2: What are the possible consequences and outcomes of implementing full inventory control in a production facility?

Depending on the maturity, size and structure of the production facility, different outcomes may come with the implementation of full inventory control. Firstly, whenever a party agrees to implement something like fully automatic inventory control to improve their inventory management, they need to understand all the implications, risks and demands that comes with such a system. As Axsäter (2015) mentions, errors due to faulty inventory records can cause problems in the short-term and the long-term. Therefore, every preventative measure necessary should be
taken to fully be able to take advantage of all the positive outcomes of such a system. As was shown in SPA, having implemented even partial inventory control can have benefits such as lowered tied-up capital, holding costs and storage area in the facility (Ruet & Vitet, 2019). This should be attractive to most parties as it goes hand-in-hand with the idea of Lean (Liker, 2004) and Industry 4.0 ideas (Kolberg & Zühlke, 2015).

As the theories, empirical data and analysis have shown, if errors and risks are properly managed and preventive measures are in place, inventory control have several benefits. The question only instead becomes on how to implement it, what technology and what equipment to use. It needs to be decided on what types of systems has the most fitting functionality and the systems need to be changed or adjusted accordingly. As has been shown in SEA, having systems that cannot directly communicate with each other (Stokic, 2019) can affect the possibility of implementing such ideas as inventory control, since the route becomes inefficient and hard to manage (Azzo, 2019). The cost for such alterations in a facility should not be underestimated, however the advantages it provides may well over-shadow the initial investment required, which has been shown in the analysis performed on the semi-fictitious case. Lower tied capital, lower holding costs, less occupied storage space, more efficient replenishment systems, freed up work-hours and a competitive advantage are a few of the positive outcomes that arrives with realizing full, or even partial, inventory control, which also can be seen in the analysis of this thesis project (Ruet & Vitet, 2019) (Axsäter, 2015). By managing to lower the number of pallets in the inventory by implementing a new way of ordering pallets and reducing the safety stock and replenishment point, you can lower both tied-up capital and holding costs.

### 6.2 SOURCES OF ERRORS

Due to a lack of information, assumptions had to be made regarding some of the numbers in the calculations, hence the semi-fictitious case. There was also a lack of literature regarding the technologies as well as a lack of benchmarking possibilities due to time limits, which made it more difficult to analyse the proposals. Lastly, the company in the case study had wishes not to publish any information they deemed sensitive and they have therefore not been used in the report. Albeit small, the consequence could be a slightly distorted result.

### 6.3 RELEVANCE OF STUDY IN COMPARISON TO PREVIOUS STUDIES

This study has examined how inventory control can be improved, and in the case study that was performed it was concluded that one way to improve the inventory control would be to make a change that would allow for a company to have more accurate tracking of their inventories. Barcode scanning, RFID and tablets were suggested as ways of achieving accurate tracking of inventory balances due to information that was found through both empirical and theoretical data. (Kolberg & Zühlke, 2015) discussed whether the lean principles had reached their limits as well as how ICT can be of importance to build further upon the existing lean principles. This study concluded that ICT (information and communications technology) can be used in order to improve inventory control which was shown with the two proposals in this study. The study is therefore
relevant to previous studies regarding this matter. The study answered the research questions from a scientific standpoint and focused only on parts that were relevant to the subject and the research questions.

6.4 SUGGESTIONS FOR FURTHER RESEARCH

• The costs and benefits of implementing IT-systems or translators between IT-systems in a production company could be studied further. By using the capital budget calculation in this report, further research can be put into finding out what types of IT systems can be developed and/or implemented.

• Further studies could compare benefits and costs between having autonomous processes and having processes that are managed by workers.

• Further studies could be made on how implementation of technology benefits inventory control for different types of production companies, a comparison could be made between a small, a medium and a big production company to see if there are any differences in benefits and costs between them and to find out what implementations suit what size of company the best.

• A similar study could be conducted as this one with more focus on the economic benefits and costs for the changes in the production company.
REFERENCES


Flodkvist, G., 2019. *Interview about EBBA + other systems* [Interview] (17 05 2019).


Stokic, R., 2019. *Interview regarding SIMAS* [Interview] (15 05 2019).


Figures

1. Ektiren, Erkan. 2019. *Example of a how a SWOT-matrix can look*
4. Healthy Simulation. n.d. *Validity & Reliability*
Appendix I

Box Process Flow Chart

Fuaad Dipka & Erkan Ekiren | May 16, 2019
Pallet Supply Flow Chart

Appendix II