LAPPEENRANTA-LAHTI UNIVERSITY OF TECHNOLOGY

LUT School of Business and Management

Business Administration

Alexandra Danielsbacka

RELEASING WORKING CAPITAL BY THE MEANS OF INVENTORY MANAGEMENT

A case of a company

Examiners: Professor Veli Matti Virolainen

Professor Katrina Lintukangas

ABSTRACT

Author	Alexandra Danielsbacka
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The purpose of this thesis was to examine ways to release working capital by the means of inventory management. The primary objective was to understand how effective inventory management affect the tied up working capital and which are the inventory management policies that should be favoured when trying to reduce the capital tied up in inventories. The research is limited to studying the impact of consumables on the tied-up working capital. The consumables in this study consists of spare parts, repair parts, protective clothing and equipment and some office supplies.

This study was conducted as an action-oriented case study. For the empirical part of the study, the used data was collected from the case company's ERP-system and the data was used for a quantitative inventory data analysis. Moreover, qualitative methods such as exploring, observation and interviews were used as data sources in this study.

The results of this thesis indicate that the case company has a lot of capital tied up in excessive and obsolete inventories. The inventory turnovers for the majority of the items are very low or zero, which means that a huge proportion of the items in the warehouse are not being consumed at all. As a solution for this, inventory levels for items with low consumption will be lowered and items with no consumption were removed from the warehouse. Moreover, the case company was suggested to conduct a multicriteria ABC-analysis in order to enhance its inventory management. As a final conclusion, it can be stated that the most effective ways to release working capital tied up in inventories are to enhancing the inventory turnover and utilizing vendor managed inventory arrangements, such as consignment stocks.

TIIVISTELMÄ

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Tämän tutkimuksen tarkoituksena on ollut selvittää, miten sitoutunutta käyttöpääomaa voidaan vapauttaa varastonhallinnan keinoin. Tutkimuksen pääasiallinen tavoite oli ymmärtää, miten tehokkaalla varastonhallinnalla voidaan vaikuttaa sitoutuneeseen käyttöpääomaan ja mitä varastonhallinnan keinoja tulisi suosia pyrkiessä vapauttamaan varastoihin sitoutunutta pääomaa. Tutkimus on rajattu tarkastelemaan kulutushyödykkeiden vaikutusta sitoutuneeseen pääomaan. Tässä tutkimuksessa kulutushyödykkeillä tarkoitetaan yrityksen varastossa pitämiä varaosia, työkaluja, korjaustarvikkeita, suojavarusteita ja -vaatteita sekä joitakin toimistotarvikkeita.

Tutkimus on toteutettu tapaustutkimuksena kohdeyritykselle. Tutkimuksen empiiristä osuutta varten aineistoa kerättiin yrityksen toiminnanohjausjärjestelmästä ja aineiston perusteella tehtiin varaston nykytila-analyysi. Lisäksi laadullisen tutkimuksen menetelmiä, kuten havainnointia ja haastatteluja käytettiin tutkimusmenetelminä.

Tutkimuksen tuloksena selvisi, että kohdeyrityksellä on paljon pääomaa sitoutuneena ylisuuriin varastoihin ja epäkurantteihin tuotteisiin. Suurimmalla osalla tuotteista varaston kiertonopeudet ovat hyvin alhaiset tai nolla, mikä tarkoittaa sitä, että varastossa olevia tuotteita ei kuluteta lainkaan. Tutkimuksen perusteella alhaisen kulutuksen tuotteiden varastotasoja päädyttiin alentamaan ja tarpeettomia tuotteita poistettiin varastosta. Lisäksi kohdeyritystä suositeltiin suorittamaan monikriteerinen ABC-analyysi tehostaakseen varastonhallintaansa. Tutkimuksen perusteella voidaan todeta, että varaston kiertonopeuden parantaminen ja toimittajien hallinnoimien varastojen, kuten kaupintavarastojen, hyödyntäminen ovat tehokkaimmat keinot käyttöpääoman vapauttamiseen.

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The last five years of studies have been the best time of my life. I have learned so much and really enjoyed my time at LUT. Although it would be lovely to continue the relatively free student life, it is now time to move into the working life. I'm happy that the huge work for the thesis is now over, although the Covid 19-pandemic made the last semester of my studies very different than before.

I would like to thank my family and friends for the continuous support during my studies and especially during the thesis writing process. I'm very pleased with the interesting thesis topic I got from the commissioner of this thesis and I would like to give my sincerest thanks to my two wonderful supervisors in the case company for all the help and support I got during my thesis project. I would also like to thank my supervisor Veli Matti Virolainen for all the help and advice for my thesis.

Kotka, 16.6.2020

Alexandra Danielsbacka

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1 INTRODUCTION

The global financial crisis in 2008 gained a lot of interest by researchers and its causes, damages to the economy and effects on macroeconomic indicators have been discussed a lot. The main reason for the financial crisis was liquidity shortages, yet working capital management (WCM) has gained less attention in the academic literature. (Kayani, De Silva & Gan 2019) However, during the financial crisis firms were forced to concentrate on working capital management and after the crisis interest towards the subject increased remarkably. In 2009 Danske Bank and Ernst & Young conducted a survey to investigate the status of working capital management in Nordic companies. The study showed that due to the decreased demand during the financial crisis, the inventories in companies had increased dramatically and therefore companies had too much capital tied up in inventories and problems with getting the required liquidity in place. (Danske Bank and Ernst & Young 2009, 4-5) Later in 2015 PwC conducted a global working capital survey which revealed that only in 2014 companies were able to reduce their working capital after the global financial crisis. The reduction was mainly a result of reductions in receivables but also inventory management affected the reduction (PwC 2015, 5). Altogether the financial crisis forced companies to pay more attention to working capital management and helped companies to understand that it's crucial to optimize the amount of their working capital.

Financial management is one of the most important areas in corporate management and it is a crucial factor in making a company successful. Previous studies have shown that the issues chief financial officers are mostly spending their time on are financial planning and budgeting as well as working capital management. Since working capital management is an important part of financial management, the importance of working capital management cannot be diminished. (Kytönen 2004, 37) In their latest working capital survey PwC (2019, 3) have stated that working capital performance have finally started to improve and they see working capital as the next value driver. Moreover, PwC conclude that receivables and inventories can be seen as major sources of opportunity for companies.

1.1 Background of the thesis

Traditionally, the academic literature has concentrated on studying long-term financial decisions and topics such as investments, company valuation and capital structures have been studied a lot, whereas the study of short-term financial decisions have gathered less attention from researchers (Baños-Cabarello, García-Teruel & Martínez-Solano 2010; Talonpoika et al. 2016). According to García-Teruel and Martínez-Solano (2007, 164) it's surprising because when examining a firm's balance sheet, short-term assets and the resources used with maturities of under one-year stand for a substantial amount. Working capital management is management of short-term assets and liabilities, and thus its importance is undeniable when considering a company's profitability, risk and even its value. Working capital represents a firm's financial health in the short run and it measures how well a company can manage its daily operations with its current assets. (Smith 1980; Deloof 2003; Raheman & Nasr 2007) Moreover, in many companies the current assets, including inventories, can be up to a half of the company's total assets and therefore, the importance of effective inventory management is evident (Raheman & Nasr 2007, 279).

Many studies have confirmed that the relationship between working capital and profitability is negative, meaning that when working capital is optimally reduced the firm's profitability increases (Deloof 2003; Baños-Cabarello et al. 2010). However, Deloof (2003) states that it is a real challenge to optimize the amount of working capital. This relays on the fact that although profitability increases when working capital decreases, the amount of working capital must not be too low because it increases the risk of inventory lacks which as for reduces profitability. On the other hand, when working capital increases, more capital is tied up to accounts receivables and inventories which for its part increases the risk of lacking liquidity. However, the increased working capital might again increase sales while the company has enough inventory to meet the increased demand on the markets. This dilemma has been studied by many researchers. Nazir and Afza (2009) have in their study researched the impact of aggressive working capital management policy on firms' profitability while Enqvist, Graham and Nikkinen (2014) have studied the impact of working capital management in different business cycles in Finland. In addition, Filbeck and Krueger (2005) have analysed working capital management and optimization results across industries.

While working capital management has been studied quite a lot from the viewpoint of liquidity versus profitability and risk, inventory management and its relationship to working capital seems to have gained less attention from researchers. However, inventory management and its policies have been studied widely, the studies seem to be focusing on special cases of inventory management, such as inventory models or spare parts inventory management. In a global working capital survey conducted by PwC (2015) came out that the main focus in inventory performance in many companies is on supply chain efficiencies, while opportunities to reduce inventories are often left on less attention. The survey also states that corporate management too often acquire funds to working capital from banks or investors rather than tries to find ways to generate more free cash flows themselves or trying to become more working capital efficient and so reduce the requirement for funding. According to a working capital survey conducted by Danske Bank and Ernst & Young (2009, 29-30) Nordic companies agreed on that their inventory management and inventory processes could be improved. The companies in the survey planned on reducing inventories during the following years mainly by reducing inventory keeping units in their production line, removing unmarketable products from inventory, dividing products into purchasing categories, using vendor managed inventory systems and creating rules for re-purchase times for each product category. This thesis studies these means in a case company context and aims at increasing the comprehension of how the means of inventory management affects a company's working capital.

1.2 Research questions and objectives

The purpose of this master's thesis is to examine how it is possible to release working capital by the means of inventory management. The main objective is to understand how effective inventory management affect the tied up working capital and which are the inventory management policies that should be favoured when trying to reduce the capital tied up in inventories. While working capital management has a significant role in the overall financial management of a company and inventory management is a part of working capital management, interesting results can be expected from the study when linking the results of the study in to the overall financial performance the company.

This thesis is done for a case company. The primary objective of this thesis is to examine ways to release working capital by the means of inventory management in this specific company. Therefore, the aim of this thesis is to offer solutions and findings mainly for the management of the case company. The need for this kind of a study has derived from increased amount of capital tied up in inventories and from the company noticing that the amount of bulk supply items had increased significantly. Therefore, this thesis aims to identify the problems in the company's inventory management processes, identify suitable methods of inventory management and material control for the target company and in addition provide development proposals for releasing working capital.

The research is limited to studying the impact consumables have on the tied-up working capital. The consumables in this study consists of spare parts, repair parts i.e. tools used when repairing something, protective clothing and equipment and some office supplies. Packing materials, raw materials, work in process and finished goods are not taken into account in this study. The study is limited to concern only consumables because it is possible to lower or change their inventory levels without directly harming the production levels or sales. The objective is to find out of which consumables it is possible to lower inventory levels and how it can be done. Moreover, the company already utilizes vendor managed inventories but their performance and their broader utilization as a way to release working capital is studied in this thesis.

The main research question is based on the research problem and the objective of the thesis. The main objective is to understand how effective inventory management affect the tied up working capital and which are the inventory management policies that should be favoured when trying to reduce the tied-up capital of inventory. The goal of this thesis is to discover ways to release working capital by the means of inventory management in the case company.

The main research question is:
"How can working capital be released by the means of inventory management?"

The main research question is supported with three sub-questions. The sub-questions help in responding the main research question. The sub-questions for this thesis are:
Sub-question 1: *"How does inventories affect working capital?"*
Sub-question 2: *"What are the means of inventory management?"*

Sub-question 3: *"What is the role of supply chain collaboration in releasing working capital?"*

1.3 Theoretical framework and limitations

The theoretical framework of the thesis starts from reviewing working capital and working capital management theory. This part aims at defining what current assets and liabilities are, how they form the working capital of a company and understanding the importance of short-term financing and working capital management. The second part of the theoretical part focuses on inventories and inventory management. In this part inventory management is defined and the need for inventories is validated. Also, different inventory policies and models are presented and evaluated, inventory performance measures are presented and the option of outsourcing inventory management is discussed. While the case company is a manufacturing company and therefore its inventories contains a lot of spare parts, also characteristics specific for spare parts inventory management is presented. The theoretical framework is demonstrated in *Figure 1*.

Figure 1. The theoretical framework of the thesis

While the findings of this thesis are mainly directed for the company itself, the theoretical part can be utilised also by other companies or for purposes of the society. The theoretical part aims to create a clear picture of the current academical research in working capital management and inventory management, as well as their relation to each other. The broad theoretical background will increase the knowledge of the subjects studied in this thesis and therefore it will have a huge impact in achieving the objectives set for this thesis. By broadly studying the academic literature the aim is to provide new ideas for the empirical part and understand the phenomenon behind the subject.

This study focuses on examining the impacts of inventory management on the tied up working capital. While working capital is studied only from inventory view point, other working capital components e.g. accounts payables and accounts receivables are not

discussed in this thesis. Therefore, the theory is also mainly focused on working capital management from the viewpoint of inventories, but in order to understand the overall picture, also the other components of working capital management are presented.

The practical limitations of this study are related to the items taken in to account in this study. The research is limited to studying the impacts of consumables in the tied-up working capital. The consumables in this study consists of spare parts, repair parts (tools used when repairing something), protective clothing and equipment and some office supplies. Packing materials, raw materials, work in process and finished goods are not taken into account in this study. Finally, considering the limitations in time and extent of the research the study focuses on how it is possible to release working capital with the means of inventory management, and does not focus on how it affects the overall profitability of the firm.

1.4 Research methodology

This thesis will be conducted as an action-oriented case study. The main objective is to find a solution to the research problem and to improve the problem. Action-oriented research approach is suitable when the aim is to understand a specific problem and find a solution for it by utilizing and combining historical data, appropriate theory and practice. (Olkkonen 1994, 74-75) This thesis also includes characteristics of a case study. In a case study intensive and detailed information of a specific case is examined (Hirsijärvi, Remes & Sajavaara 2007, 130-131).

This research includes aspects from both qualitative and quantitative research methods. However, this research is conducted as a qualitative research. The qualitative research methodology is the most reasonable when considering the subject and research questions of the thesis. According to Metsämuuronen (2011, 220) qualitative research is best suited when the interest is in the detailed structures of events and the goal is to understand the phenomenon being studied.

The empirical part is started by doing a quantitative inventory data analysis of the current situation in the case company by collecting reports and statistical data from the enterprise resource planning system. After that qualitative methods such as exploring, observation and interviews are used as data sources. Data and findings gathered from these data sources are

utilized so that the case company can't be recognized and no confidential information is revealed. The confidentiality of the thesis can be seen as a major challenge in this part and it might cause that some parts of the work must be kept as a secret.

1.5 Structure of the study

This study is organized as follows. The chapter two discusses theory of working capital and working capital management. In chapter three, theory of inventory management is discussed broadly. Chapter four presents theory of the chosen research methodology and how data was collected. Chapter five is the actual empirical part of the thesis and investigates the phenomenon in question within the case company context. The aim in this part is to find a solution for the research problem and the current challenges the company faces within this subject. Finally, in chapter six the main findings of the research are presented and limitations, reliability and validity of the study are discussed and topics for further research are suggested. The structure of the study is demonstrated in *Figure 2.*

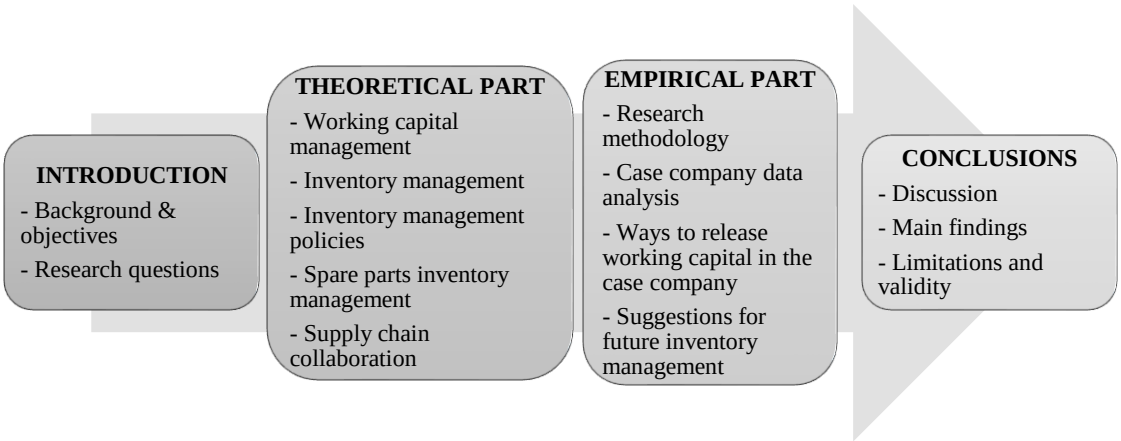

Figure 2. Structure of the thesis

1.6 Key concepts

Working capital management (WCM) is a company's short-term capital management, which includes the management of current assets, current liabilities and inventories (Corelli 2018, 371). It's an important part of corporate management and strategy, and especially a crucial part of corporate financial management and it gives the direction for the daily financial decision of the company (Kayani, De Silva & Gan 2019, 356). A crucial task of

working capital management is to ensure that WCM components are used effectively. The components of working capital management are accounts receivables, accounts payables, cash conversion cycle and inventory. (Baños-Cabarello et al. 2010, 513-514)

Inventory management is management of a company's physical assets by making sure that there are enough inventories to meet the necessities of the production but yet avoiding excess inventories. It also involves constant and cautious consideration of factors that affects it, as well as scheduling of future purchases and reviewing of existing stock levels. (Corelli 2018, 391) By effective inventory management the firm can avoid unwanted delays in the production and ensure that its resources are effectively used while capital is not tied in excess inventories (Corelli 2018, 406). Inventory management has two principal goals. Firstly, ensuring that there are enough inventories to maintain operations and secondly, reduce the ordering and upholding costs of the inventories to the minimum. (Ehrhardt and Brigham 2011, 661)

2 WORKING CAPITAL MANAGEMENT

Corporate financial management can be divided in three functions: long-term assets management (capital budgeting), long-term capital management (capital structure management) and management of short-term assets and liabilities (working capital management). Working capital management can for its part be divided in four functions: cash management, inventory management, credit management and management of short-term liabilities. (Kytönen 2014, 37, 44) The framework of financial management is demonstrated in *Figure 3.* The significance of short-term financing must not be diminished because the long-term profitability of a firm is based on effective management of working capital. Effective management of short-term financing ensures that corporate resources are used effectively, hence the corporate can achieve its main purpose – maximizing the wealth of the shareholders. (Corelli 2018, 380) This thesis focuses on the short-term financing of a company, in other words on working capital management, from the viewpoint of inventory management.

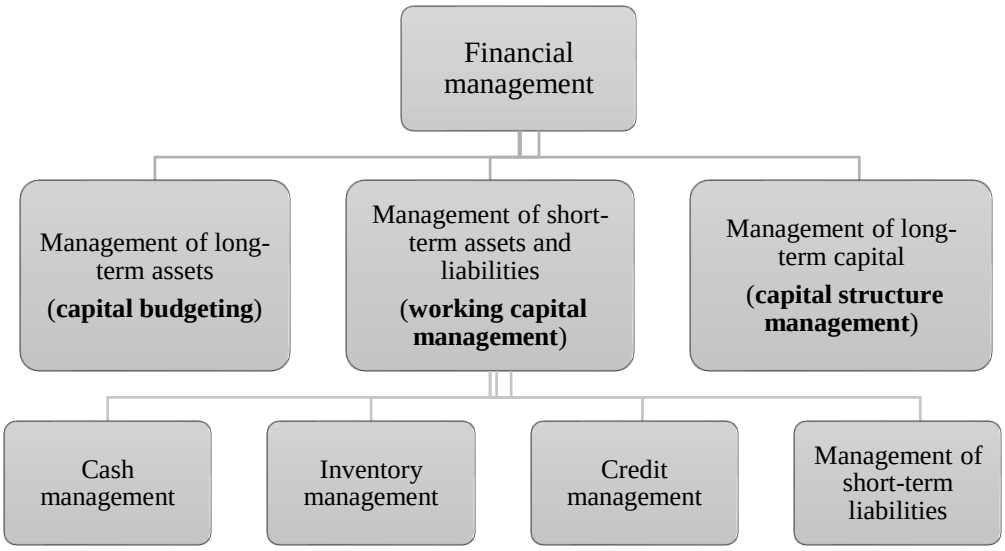

Figure 3. The framework of financial management

2.1 Defining working capital

Already in the beginning of the 20th century Mann (1918, 340) defined working capital (WC) as the money that an entity needs to perform its existing operations. In other words, it is the amount of capital needed to keep the business running and is also known as net working

capital. Besley and Brigham (2008, 48-49) on the other hand define WC as investments that a company makes in its short-term assets, including cash, accounts receivables, accounts payable and inventory. According to Talonpoika, Kärri, Pirttilä and Monto (2016, 277) working capital can be divided in three separate pieces: net working capital, operational working capital and financial working capital. The net working capital, also referred as just working capital, is the differential between a company's current assets and current liabilities (Marttonen, Monto & Kärri 2013, 431). In the operational working capital are included accounts receivables, accounts payables and inventories. Financial working capital on the other hand consists of those parts of net working capital which are not included in the operational working capital, for example cash. In this study, the focus is on operational working capital.

Current assets are a company's cash, receivables and other assets that the company can convert to cash within a short time, usually less than 12 months. Raheman and Nasr (2007) have defined current assets as those assets that in normal course of business are returning to the company as cash within a short time. Current assets are for example cash, accounts receivables, inventories and prepaid expenses. Cash is defined as money that is on those company's accounts where customer payments are received and business expenses are paid. Accounts receivables are all those credits the company has towards its customers and waiting to be completed as sales transactions in the near future. (Corelli 2018, 11-12)

Current liabilities are those obligations that should be paid within 12 months. Current liabilities are for example short-term notes payable, accounts payable, dividends payable, payroll liabilities and unearned revenue. Short-term notes payable are notes that should be paid within 12 months e.g. a working capital loan from a bank. Accounts payable is that money the company owes to its suppliers, for having acquired materials, items or services. Current assets are usually used as a settlement of the current liabilities because they are usually paid either with the cash on the company's accounts, collecting accounts receivables or by selling inventories. (Corelli 2018, 12-13)

2.2 Working capital management

Working capital management (WCM) is an important part of corporate management and strategy, and especially a crucial part of corporate financial management affecting its

performance and liquidity. Working capital management gives the direction for the daily financial decision of the company. (Kayani, De Silva & Gan 2019, 356) Preve and Sarria-Allende (2010) have defined that WCM includes a firm's decisions related to current assets and current liabilities, while Thachappilly (2009) have defined it to be management of the flow of funds. Marttonen, Monto and Kärri (2013) have stated that "*operational working capital management, including inventories, accounts receivable and accounts payable, is an important part of short-term finance and asset management".* In their study Baños-Cabarello et al. (2010, 513-514) have stated that the most important part of working capital management is to ensure that WCM components are used effectively. Fundamentally, management of operational working capital can be seen as balancing between reducing the amount of tied up capital in processes and current assets, which helps in increasing the profitability and minimizing the risks that too small amount of operational working capital i.e. liquidity shortages causes (Marttonen et al. 2013, 431).

There are many reasons why working capital management is important. Firstly, according to Raheman and Nasr (2007, 279) in manufacturing companies the amount of current assets can be up to a half of the company's total assets and in distribution companies the ratio can be even higher. Therefore, excessive levels of current assets may end up in small returns on investment. Secondly, it is important that by effectively managing working capital the company can avoid problems in meeting its short-term obligations. (Raheman & Nasr 2007, 280) Also, García-Teruel and Martínez-Solano (2007) argue that while working capital management evidently affect a company's profitability and risk, and consequently its value, it is important that with effective working capital management the company finds a balance between those decisions that increases the company's profitability and those decisions that increases the risk. Moreover, if a company manages to minimize the amount of capital tied up in current assets, it is able to reduce its financing cost and/or have more capital available for expansion and development of the business (Filbeck & Krueger 2005). Working capital can also work as a buffer when things are not going as well as they should and when the company wants to sell on credit in order to promote sales. Poor management of working capital, more precisely poor management of cash, can also result in losses of cash discounts in accounts payables or the company losing its reputation due to delayed payments. (Corelli 2018, 359)

Two basic types of working capital management strategies have been presented in the literature: (1) minimizing of the working capital investment i.e. the aggressive working capital policy and (2) adopting working capital policies that increases sales. (García-Teruel and Martínez-Solano 2007; Baños-Cabarello et al. 2014) In the first policy i.e. the aggressive working capital policy companies are aiming at minimizing the amount of working capital by shortening the cycle times of inventories and accounts receivables, as well as by increasing the cycle time of accounts payable (Marttonen et al. 2013). This aggressive strategy is however associated with higher risk, mainly because the company is more vulnerable for liquidity shortages and the possibility for stockouts is higher. (Ng et al. 2017, 663) However, Marttonen et al. (2013) note that it is not reasonable to minimize the amount of working capital in all cases, rather the amount of working capital should be optimized and managed considering the specific company and its current state. In the second policy, where working capital policies that increases sales are adopted, companies hold higher working capital levels in order to be able to meet increased sales and for achieving greater cash discounts for early payments. (Deloof 2003; Baños-Cabarello et al. 2014) On the other hand, holding higher working capital levels requires financing and therefore, companies have higher expenses of external financing and are thereby more vulnerable for going bankrupt. (Baños-Cabarello et al. 2014, 332) According to Lazaridis and Tryfonidis (2006, 26) the working capital management strategy is usually based on the size and profitability of the company. For example, in general small companies seems to be focusing more on inventory management, while less profitable companies are focusing on credit management routines. Moreover, companies that are aiming at high growth, should limit their credit policy towards their customers, because they have more capital tied up in inventories so that they can respond to the increased demand.

The importance of working capital management is emphasized in small and medium-sized companies (SMEs) because in SMEs most of the assets are in the form of current assets. Also, in SMEs the main source of external finance tends to be current liabilities because SMEs face more problems in obtaining financing from the long-term capital markets. In previous academic research it has been proven that there is a negative relation between the profitability of a SME and the number of days accounts receivable and days of inventory. (García-Teruel & Martínez-Solano 2007; Baños-Cabarello et al. 2010) Moreover, Baños-Cabarello et al. (2010) and Padachi (2006) argue that especially for small companies effective working capital management can be the only way to survive and grow.

The components of working capital management are accounts receivables, accounts payables, cash conversion cycle and inventory (Baños-Cabarello et al. 2010; Corelli 2018; Kayani et al. 2019). Accounts payables is the amount of money a firm owes to its suppliers, in other words simply the amount of unpaid purchases to the supplier. They are handled as debts and in the balance sheet they appear as liabilities. Accounts receivables on the other hand is the amount of money owed to the company and it originates for example when the company provides its products for the customer on credit. (Corelli 2018, 384, 387) The cash conversion cycle (CCC) measures the cycle of working capital, which means the time from the product being purchased or produced to inventory to the time it is sold and the cash is received (Ehrhardt & Brigham 2011, 648). Inventory is a company's stock of physical assets that has economic value, waiting to be packed, processes, transformed, exploited or sold in the future (Corelli 2018, 391). *Figure 4* demonstrates the operating cycle of these WCM components and how they are linked to each other.

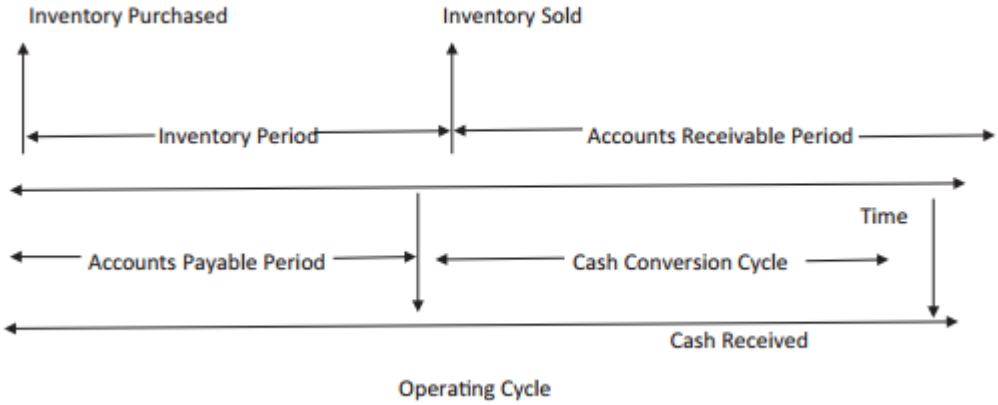

Figure 4. The operating cycle of the components of WCM (Kayani et al. 2019, 356)

Usually companies focus on different components of working capital management. Although the components of working capital (accounts payables, accounts receivables and inventory) have been already explained, the next sub-chapters discuss their role as WCM components and how they effect on the operating cycle presented in *Figure 4*.

2.2.1 Accounts receivables management

Accounts receivables are all those credits the company has towards its customers and waiting to be completed as sales transactions in the near future, originated from the company providing its products for the customer on credit (Corelli 2018, 11-12). When trying to

minimize the amount of working capital, it would in theory be justifiable that the amount of accounts receivables would be as small as possible and trade credit would not be granted for customers. However, this rarely works in the practice. For example, according to Brahmi et al. (2020, 87) customers tend to order in larger quantities if trade credit is granted. Also Ng et al. (2017, 663) argue that especially in manufacturing companies, where customers are often offered trade credit, extensions in credit periods for important customers promotes sales. Some companies also use trade credits as a way to attract new customers (Lazaridis & Tryfonidis 2006). Correspondingly, if trade credits for customers are decreased, the sales can decrease and customer relationships can be harmed (Marttonen et al. 2013). Moreover, trade credits can have a positive impact on sales while the customer has the possibility to evaluate the quality of the product before payment (Raheman & Nasr 2007, 280; Lazaridis & Tryfonidis 2006)

2.2.2 Accounts payables management

Accounts payable is the money the company owes to its suppliers for having acquired materials, items or services. (Corelli 2018, 12) When trying to minimize the amount of working capital, it would in theory be justifiable that the amount of accounts payables would be as large as possible by requiring long payment periods from suppliers. Hence, when the payment periods are long, the company does not have to have enough capital to pay off its accounts payable, because fresh income is constantly being generated in sufficient levels to cover its current expenses. However, when the payment periods are long, the company cannot utilize possible early payment discounts and therefore in the long run the costs are much bigger than they could have been. (Raheman & Nasr 2007; Marttonen et al. 2013) Raheman and Nasr (2007, 282) argue that it is usually the less profitable companies that wait longer to pay their bills. Moreover, Brahmia et al. (2020, 87) state that in some cases companies may extend accounts payable beyond the due date and it can be justifiable when the company is low on working capital and the stockout costs exceed the payment default penalty.

2.2.3 Inventory management

Inventory is a company's stock of physical assets that has economic value, waiting to be packed, processes, transformed, exploited or sold in the future (Corelli 2018, 391). Especially in manufacturing firms the inventories present a large share of the company's total assets while the company must keep materials in inventories to ensure the continuity of the production. (Ng et al. 2017, 663). Moreover, keeping larger inventories can be tempting while it may lead to higher sales and smaller risk of stockouts (Raheman & Nasr 2007; Marttonen et al. 2013). On the other hand, if inventory levels are big, the company can be in trouble if sales suddenly drop and therefore inventory mismanagement can lead to excessive amounts of capital being tied up in inventories (Lazaridis & Tryfonidis 2006, 35). Instead of trying to choose whether to hold smaller or larger inventory levels, the company should rather make sure that the inventory turnover in days is reduces to a reasonable minimum i.e. make sure that inventories are not staying in the warehouse for too long (Raheman & Nasr 2007, 294). Moreover, Padachi (2006, 47) argue that although a company would be very profitable, but it is not able to transfer its inventory into cash within the same operating cycle, the company must seek for external financing to support its continued working capital needs. A prolonged cash operating cycle may again increase the profitability of a company by promoting sales, but on the other hand it may also decrease the profitability if the costs of holding excessive inventories exceeds the benefits of it. This is however a very narrow overview of inventory management and therefore chapter three discusses inventory management in more detail.

2.2.4 Cash Conversion Cycle (CCC)

To measure working capital, previous studies have used measures based on the Cash Conversion Cycle (CCC) (Deloof 2003; Padachi 2006; Garcia-Teruel & Martinez-Solano 2007; Baños-Cabarello et al. 2010). The cash conversion cycle (CCC) measures the cycle of working capital, which means the time from the product being purchased or produced to inventory to the time it is sold and the cash is received (Ehrhardt & Brigham 2011, 648). Enqvist et al. (2014, 39) have defined CCC, measured in days, as "*the length of time between a company's expenditure for the procurement of raw materials and the collection of sales of finished goods"*. The CCC can be calculated as follows:

$$CCC = Number\ of\ Days\ Inventory\ (DIO) + Number\ of\ Days\ Accounts\ receivable\ (DSO) - Number\ of\ Days\ Accounts\ Payable\ (DPO)$$

The relation between the cash conversion cycle and company's profitability is evident. By shortening a company's CCC the profitability a company can be improved (Lazaridis & Tryfonidis 2006; Garcia-Teruel & Martinez-Solano 2007). A company can have different ways to manage the components of the CCC so that the overall profitability of the company can be maximized or the growth of a company can be enhanced (Lazaridis & Tryfonidis 2006, 27). Basically, the longer the CCC is, the larger are the funds that are tied up as working capital and therefore the longer CCC indicates that the company is in a need of additional capital. Moreover, with a longer CCC the company can try to increase sales due to higher inventory levels and thereby having a possibility to respond to increased demand. (Baños-Cabarello et al. 2010, 512, 514) However, in general the idea is that by shortening the CCC, the profitability of the company can be increased (Deloof 2003; Garcia-Teruel & Martinez-Solano 2007).

Finally, the cash conversion cycle can be seen as one of the most important parts of working capital management. From a company's cash conversion cycle, it can be drawn conclusions of how much the company invests in customers and inventory, and how much of the purchased materials are purchased at credit from suppliers. (Garcia-Teruel & Martinez-Solano 2007) As a conclusion of the cash conversion cycle Lazaridis and Tryfonidis (2006, 35) state that "*by correctly handling the cash conversion cycle and keeping each different component of working capital management (accounts receivables, accounts payables and inventory) to an optimum level, managers can create profits for their companies*".

3 INVENTORY MANAGEMENT

As a crucial part of working capital management, inventory management should be considered as an important part of a company's overall financial management. Inventory management is management of a company's physical assets by making sure that there are enough inventories to meet the necessities of the production but yet avoiding excess inventories. It also involves constant and cautious consideration of factors that affects it, as well as scheduling of future purchases and reviewing of existing stock levels. (Corelli 2018, 391) According to Ehrhardt and Brigham (2011, 661) inventory management has two principal goals. Firstly, ensuring that there are enough inventories to maintain operations and secondly, reduce the ordering and upholding costs of the inventories to the minimum. Tersine (1988, 13) have stated that the objective of inventory management is *"to have the appropriate amounts of raw materials, supplies and finished goods in the right place, at the right time and at low price".* Inventory management defines a company's supply chain process quality and the impacts of the financial health of the balance sheet. By effective inventory management a firm can avoid unwanted delays in the production due to lacks in inventory and ensure that its resources are effectively used while capital is not tied in excess inventories (Corelli 2018, 391, 406).

Decreasing the amount of capital tied up in inventories is an important part when decreasing the amount of working capital. However, this should be done without weakening the efficiency of the firm and harming the production. (Filbeck & Krueger 2005) The challenge is that decreasing inventory levels usually targets for producing less and hence, lowering overhead absorption rates. However, when aiming to release the working capital tied up in inventories, the most efficient way is to rebalance the mix. In order to do so, the fundamental logic of stocking and replenishment decisions must be finessed to follow the demand. By doing this the company is able to produce and sell more with a lower inventory balance, while simultaneously improving margins due to obsolescence write-offs, order expediting and reduced overtime. (EY 2015, 2) According to Blinder and Maccini (1991) a company should be careful not to lower inventory levels excessively, while too low inventory levels might expose the company for interruptions in the production and delivery problems. If the company is not able to answer to the demand or delivery times are too long, it can lead to

loosing the sale. In the end inventory management can be seen as balancing between risk and availability.

Different types of organizations have different inventory problems. Organizations are usually divided in retail, wholesale/distribution and manufacturing/assembly. The case company for this thesis is a manufacturing company and they usually have the most difficult and complex inventory problems, while they purchase raw materials and change their form to create value as finished goods. (Tersine 1988, 4-5) The importance of inventory management for a company can be assessed by the overall investment in inventory and the extent of material costs for all products. The overall investment in inventory can be discovered from the balance sheet of the company by comparing the investment in inventories to current assets or total assets. If this percentage is big, effective inventory management is extremely important. Similarly, if material costs are a large percentage of the total costs of the product, it is particularly important to pay attention on inventory management. (Tersine 1988, 20-21) However, in any type of organization the fundamental objective of inventory management is to maintain inventories at such a level that the goals and objectives of the company can be achieved (Tersine 1988, 20). Finding the optimum level of inventories for a specific company is what inventory management is all about.

Inventory management policies can roughly be divided in keeping own inventories and inventories owned by the supplier. Inventories owned and managed by the company itself usually follow the traditional order-to-delivery process (OTD), according to which the purchasing process contains four sub-processes: customer's order, supplier's delivery, transportation by the logistics service provider and the customer's product receipt sub-process (Forslund, Jonsson & Mattsson 2009, 41). Alternatively, if the inventories are owned by the supplier, inventory models such as consignment stock (CS) and vendor managed inventory (VMI) are common. In this chapter basic theories, policies and models of inventory management are discussed.

3.1 Defining inventories

Inventory is a company's stock of physical assets that has economic value, waiting to be packed, processed, transformed, exploited or sold in the future (Corelli 2018, 391). Tersine

(1988, 4) has divided inventories in four different inventory types: supplies, raw materials, in-process goods and finished goods. *Raw materials* are items that the company purchases from suppliers and are used as inputs into the production process and modified or transformed into finished goods. *In-process goods* are unfinished goods that are partially completed final products, still being in the production process. *Finished goods* are the final product that are being sold, distributed or stored. Tersine have defined *supplies* as inventory items being consumed in the normal functioning of an organization but not being a part of the final product. Some examples of supplies are pencils, paper, light bulbs and facility maintenance items. Factory supplies can be called MRO, for maintenance, repair and operating supplies. Muller (2003, 5) on the other hand argue that items used in operations should be considered from a functional standpoint, according to which inventory that isn't raw materials, work in process or finished goods, can be further divided in consumables and service, repair, replacement and spare items. Consumables are used in many operations and include items such as hand towels, cleaning items, copying paper, light bulbs and packing materials. The service, repair, replacement and spare items are used in the maintenance of machines or as spare parts for a customer's machine if it sometime in the future will need service and repair.

Inventories can also be divided into functional classifications: (1) working stock, (2) safety stock, (3) anticipation stock, (4) pipeline stock and (5) decoupling stock. *Working stock* or *cycle stock* is the inventory that is being held in the warehouse in advance of requirements so that the company can order in lot sizes and not only for true need. *Safety stock* is the inventory that is being held in the warehouse in case of uncertainties in supply or demand. *Anticipation stock* is inventories that are being built up in advance for seasonal demand peaks. *Pipeline stocks* are inventories that have left the company's warehouse but are still in the company's distribution chain waiting to be bought by external consumers or inventory that is being transported over long distances. (Tersine 1988, 8) In addition to these, some inventories can also be referred as *dead stock*. Dead stock is inventory with no demand i.e. obsolete inventory, and it is wasteful, because it is subsidized with the profits gained from other production. (Lai & Cheng 2009, 80-81)

Above inventory is used as a concept for a company's physical items in the stock. However, the concept inventory can also refer to the physical space e.g. hall, where the products, items and components are stored. It can also be used as a concept for a logistic wholeness, which

means that inventory can be located in e.g. distribution centres, stores or delivery van, although these are not really physical storages. (Ballou 1992, 403-44) The concept inventory can also be used when referring to the value of inventory, e.g. in accounting (Karrus 2003, 35). According to Sakki (2009, 103) the concept inventory usually covers all current assets of the company. For clarity reasons, in this thesis the physical space e.g. hall where the products are located, are for now on referred as warehouses.

3.1.1 Motives for holding inventories

There are many reasons for companies to hold inventories. According to Karrus (2003, 22) most companies have inventories in order to secure product deliveries for customers and moreover inventories are necessary when demand is uncertain and suppliers have long delivery times. Baños-Cabarello et al. (2010, 513) have in their study stated that with the help of larger inventories a company can protect itself from undesirable interruptions in the production process and therefore missing revenues due to lack of products to sell. Furthermore, stockout costs i.e. the economic consequence of an external or internal shortage, is the fundamental motive for holding inventories. External shortages occur when a customer's order is not filled and may cause backorder costs, costs of losing the potential sale and future profit loss. Internal shortages may cause lost production and delays in completion date. (Tersine 1988, 14-15) Niskanen and Niskanen (2000, 354-355) have identified the following four different motives and strategies for holding inventories:

1. The most popular strategy is the business motive, according to the which companies hold inventories in such a level that they always can reply to the demand.

2. A company holds excessive inventories in order to meet the demand also in unexpected situations, when the demand is considerably higher than in normal situations. Certainly, this strategy is highly capital intensive while the inventory levels are always over exaggerated.

3. Companies hold larger inventory levels because they expect that the market prices are increasing in the future. Hence, holding excessive inventories is a tool for companies to protect themselves from price fluctuations.

4. The company is forced to hold a specific, pre-agreed inventory level that is determined in the contract.

Fundamentally, inventories are held because of replenishment lead times, which is the time lag between making the order for the supplier and finally receiving the order from the supplier. Large inventories can also help in reducing supply costs e.g. in form of quantity discounts. (Baños-Cabarello et al. 2010, 513) Vrat (2014, 23) have also identified pipeline inventories as one reason for companies to hold bigger inventories. One objective of pipeline inventories is to speed up the supply chain.

3.1.2 Inventory disadvantages

Although there are many reasons to hold inventories, there equally are many reasons to not hold too much inventories. First of all, inventories tie up working capital. In many organizations it is a remarkable amount of capital and on in some cases on the company's balance sheet up to 40% of the company's current assets can be tied up in inventories. Thus, it is obvious that poor control of inventory can result in negative cashflows, limit the expansion of a company through lack of capital and reduce the return on investment by broadening the investment base. It should also be considered that the capital invested in inventories could be used somewhere else for profit making, debt servicing or dividend distribution. (Tersine 1988, 20-22) Karhunen, Pouri and Santala (2004, 305) argue that one big disadvantage of holding inventories is that it is not free for companies and another problem is that in principle inventories do not create value for the customer in any other way than product availability, but only causes costs.

The products held in inventory can also become outdated either technically or economically. Product contamination is typical in the food industry, but also information technology products can lose their value over time, even though their technical quality wouldn't deteriorate. (Haverila et al. 2009, 446) The more the company has stock items i.e. stock keeping units (SKUs) in its warehouse, the bigger is the risk for an individual product to become outdated. Similarly, the higher the inventory levels are, the bigger are the costs if the products become outdated. The outdated products can lead to substantial losses and in some cases, it is possible that the company additionally is forced to pay disposal fees of a product it has paid a full price of. According to Karrus (2003, 28) it is possible to decrease

the amount of capital tied up in inventories by holding the inventory levels low and keeping the inventory turnover ratio high. Therefore, it is recommended to keep the inventory levels low and inventory turnover high especially if the risk of the products being outdated is high. It has been verified that the number of days in inventory and the profitability of a company actually have a negative relationship, which means that if the inventory levels have grown uncontrollably and suddenly the sales drop, the company is in a situation where capital is tied up in inventory instead being in use for profitable operations (Lazaridis & Tryfonidis 2006).

3.1.3 Inventory costs

Inventories cause costs all the way from the beginning when the inventory is bought to the end when the inventory is stored and managed until it is used or sold to the customer (Corelli 2018, 393). According to Muller (2003, 2) inventory costs are in general divided in ordering costs and holding costs but they cause costs also when the warehouse worker receives, checks the quality, finds a place for the product in the warehouse and finally collects the product from the warehouse when it is needed. Also deterioration, damage, obsolescence and even theft can cause inventory costs. Although keeping inventories always causes costs, companies should always keep a safety stock because of uncertainties in supply and demand, and furthermore because of the lead-times in production and transportation (Axsäter 2015, 1). Inventory management and inventory policies affect cost directly and revenue only indirectly. It is noteworthy, that inventories don’t generate revenues but only makes revenue generation possible. It is sales that generate the revenues. (Tersine 1988, 20)

In the previous academic literature, the costs of holding inventories have been defined variously. Sakki (2009, 56) have divided the costs of holding inventories in three sections: interest costs of current assets, costs of the space where the inventories are held and devices used there, and costs of waste and outdated products. Simchi-Levi et al. (2003, 32) on the other hand have also identified three sections, but from another perspective. Firstly, costs of holding inventories consists of handling costs, such as labour and operating costs. Secondly, fixed costs, which are not directly affected by the inventory levels but by the size of the warehouse. Thirdly, storage costs which consists of the maintenance costs of the inventory

and are directly commensurate with the annual average inventory levels. Moreover, Haverila et al. (2009, 444) have listed five costs of holding inventories:

1. Interest costs of the tied-up capital. The amount of interest costs is usually approximately 10-20 % of the total inventory value and hence, is the biggest single cost of holding inventories especially if a lot of external capital is required.

2. Costs of the storage. These costs are for example rental and maintenance costs of the warehouse space and are usually 1-5% of the total inventory value.

3. Labour costs of the employees working in the warehouse. This is usually 1-5% of the total inventory value.

4. Costs of waste. These costs are mainly due to obsolescence, theft, bad maintenance of inventory information and delivering wrong products for the customers, but also the number of storable items and the number of warehouses affect the waste costs. These are usually 2-5% of the total inventory value.

5. Insurances taken for the inventory. Insurances are usually under 1% of the total inventory value.

When taking into account all of the above-mentioned inventory costs, the annual total inventory costs are about 20 – 36 % proportionated to the total inventory value (Haverila et al. 2009, 444).

3.2 Inventory policies

Inventory management and control is a common problem for all companies' despite of the industry. The objective of inventory management is to maintain inventories at a level where the set goals of the company can be achieved. Inventories and inventory policies cause direct costs for the company but revenues only indirectly by making the revenue generation possible. (Tersine 1988, 29) The functionality of inventories is the most effective when there are no delivery incapabilities i.e. the inventory levels are high enough to always meet customer demand. However, holding excess inventories causes a lot of costs for the company and hence the inventory levels should be minimized without worsening the company's capability to meet the customer demand or the requirements of the production. (Karrus 2003, 35). This is the fundamental conundrum of holding inventories. According to Tersine (1988, 17) if the company focuses too much on holding the inventory turnover high i.e. lower

inventory levels, it can result in higher unit costs, while the company has to make smaller, more frequent purchases. However, if the company focuses on keeping the unit costs low, it results in higher inventory levels and therefore reduces inventory turnover.

The items that arrive to the company's warehouse are usually stock replenishments, which means that the received product is a part of the company's stock items, i.e. stock keeping units, and is taken into the warehouse to wait for the moment of sale or to be used in the production (Karhunen et al. 2004, 382). Companies should carefully consider which stock items they want to keep in their inventory and which products can be ordered only when they are needed. Holding unnecessary stock items tie up capital to no avail, take up storage space even at low inventory levels and cause both storage and administrative costs. The basic rule is that the benefits of a single stock item should be higher than the harms of not keeping the item in the stock. (Ritvanen & Koivisto 2007, 34) The need to store a specific stock item should be considered case-specific. In many cases it is not reasonable to store the item by the company but rather ensure fast and reliable availability from suppliers. (Karrus 2003, 35) According to Haverila (2009, 450) for instance expensive stock items that have short delivery times, should be considered to order only when needed rather than keeping them in stock waiting to be used.

In a nutshell, inventory management should determine the right ordering quantities when considering future demand by simultaneously avoiding overstocking and understocking, try to avoid losses caused by spoilage and inventory obsolescence, and furthermore minimize total inventory costs and increasing efficiency (Nagen et al. 1994). In the next chapters, most common inventory and material management concepts and theories are further discussed. According to Niemi et al. (2009, 160) companies however do not often base their inventory management decisions on theories and the theories used in companies are quite elementary. This is mainly due to the fact that inventory management theories are very diverse from the practice and although their benefits could be shown, their adaption into practice is not always straightforward and easy.

According to Axsäter (2015, 41) the most commonly used ordering policies, also sometimes referred as inventory policies, are (R,Q) policy and (s,S) policy. According to the (R,Q) policy the company orders a batch quantity of size Q when the inventory level decreases under the predetermined reorder point R. The (s,S) is similar to the (R,Q) policy but when

the inventory level decreases under the predetermined reorder point *s*, the company orders a batch so big that the maximum level of inventory *S* is reached. The (R,Q) and (s,S) policies are very practical and probably the most used inventory policies amongst companies due to their simplicity. However, there are also many other inventory policies and models how to calculate the right order quantities and reorder points in different circumstances. In the next chapters inventory policies are discussed from different viewpoints. Firstly, different inventory systems. i.e. how materials are managed, are presented and secondly different deterministic and probabilistic inventory models in independent demand systems are presented. In this thesis the theoretical part focuses only on inventory models in independent demand systems, because the thesis is limited to studying consumables, which demand is independent.

3.2.1 Materials management

The management of materials is firstly determined by the nature of demand of the inventory items. Basically, demand for the items in the warehouse can be independent or dependent. *Independent demand* means that there is no relationship between the demand for an item and any other item, for instance end items and products usually are independent. *Dependent demand* on the other hand means that the demand for an item is directly related to or the result of demand for a "higher level" item, and this is usually the case with raw materials, components and subassemblies. Usually the demand of independent items is less deterministic and therefore their management is based on forecasting, e.g. probabilistic inventory models. (Tersine 1988, 10)

Every company has its own information system e.g. ERP-system for materials management. Sakki (2014, 81) however argue that materials are still controlled a lot manually, although determining the safety stock and reorder point in to the information system could help in lowering the amount of capital tied up in inventories. According to Sakki (2009,120) the traditional approach to material control is *inventory-based control*, where the information of the need to purchase an item can be obtained from the inventory balance. This kind of material control is convenient for stock items that are continuously consumed but the fluctuations in demand can be vigorous. The inventory-based control is usually the most suitable for items with independent demand (Sakki 2014, 90). Inventory-based control can

also be referred as *perpetual inventory system*, which Tersine (1988, 11) has defined as a system that "*orders stock every time the inventory position reaches a reorder point and so records must be maintained of all inventory transactions".*

In manufacturing companies, the approach for material control is usually different, because the required components and raw materials, and how much they are needed, is based on the manufacturing volume of the final product i.e. the demand for materials is dependent. In situations of dependent demand there might be very long periods when there are no demand and therefore, in contrast to inventory-based control, usually no safety stocks are kept. In these cases, the material control methods are usually divided in material requirements planning (MRP) and the pull system, and these are usually referred as *order-driven control.* (Sakki 2014, 90) The *material requirements planning (MRP)* system orders stock only to meet preplanned production requirements (Tersine 1988, 11). The MRP system is sometimes also referred as the *push system*. In this approach required materials are ordered or produced to the warehouse based on sales forecasts of the final product, bill of material (BOM) i.e. the product structure and current inventory levels. In the *pull system*, as the name implies, the materials pulled through the supply chain, meaning that materials and products are pulled from the preceding stage. Just-in-time approach is one example of a pull-based inventory flow. (Sakki 2014, 90-91)

3.2.2 Deterministic inventory models in independent demand systems

In deterministic inventory models, the used parameters and variables are known or they can be calculated with certainty, or in other words they are constant. The required parameters that should be able to present as deterministic values are demand forecasts, appropriate inventory costs and lead times. In the real world these parameters are seldom possible to know with assurance and therefore for example demand forecasts and lead times are more reasonable to present as probabilistic terms. However, deterministic inventory models are useful for determining approximate values and can be used to describe inventory phenomena. (Tersine 1988, 90) This classical inventory model, where demand and lead times are deterministic, is demonstrated in *Figure 5*.

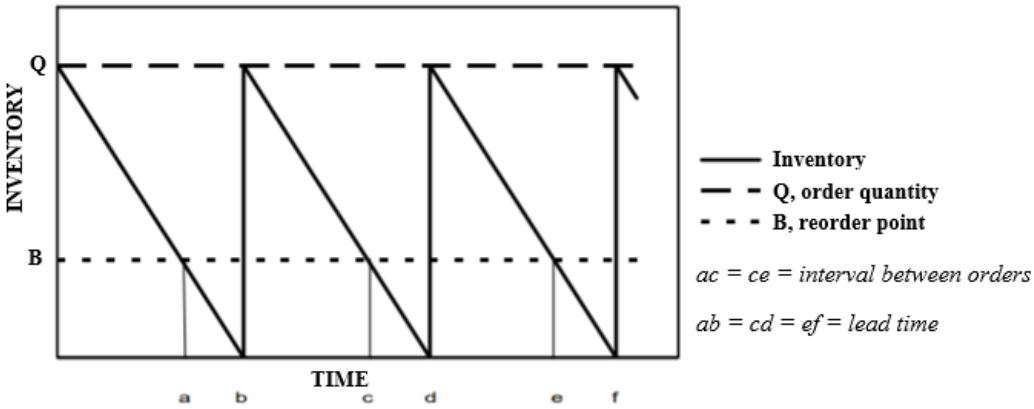

Figure 5. The classical inventory model (Tersine 1988, 92)

3.2.2.1 Economic Order Quantity (EOQ)

When using the traditional order-to-delivery (OTD) process, the most common inventory model to solve problems of when to order and how much to order is the Economic Order Quantity (*EOQ)* model (Eiselt & Sandblom 2010, 343). The EOQ-model is a simplified model illustrating the trade-offs between ordering and storage costs and is applicable only for items with constant, deterministic demand. The objective of the model is to determine the order quantity that minimizes annual purchasing and carrying costs, and at the same time is able to meet all demand. (Simchi-Levi 2003, 47) The economic order quantity can be calculated with the following formula:

$$EOQ = \sqrt{\frac{2KD}{h}} = \sqrt{\frac{2KD}{PF}}$$

In the formula, K = fixed ordering costs (€/order), D = yearly consumption (pieces) and h = holding cost per unit per year, P = purchase cost of an item and F = annual holding cost as a fraction of unit cost. As a result, items with high unit costs are being ordered frequently in small quantities and items with low unit costs are ordered in large quantities. (Tersine 1988, 93) When the yearly demand (R) and lead time (L) are deterministic, the reorder point (B) that determines when the EOQ is ordered, can be calculated as follows:

$$B\ (when\ L\ is\ months) = \frac{RL}{12}\ or\ B\ (when\ L\ is\ weeks) = \frac{RL}{52}$$

When using this model, it is extremely important to take into account that the demand of the item should be known and constant, and be divided evenly on the period under review. In addition, the price of the item should not change significantly and the warehousing, transportation and ordering costs should not change and depend on the order quantity. Moreover, the delivery time of the item should be known and remain constant. (van Weele 2014, 247) The model has been criticised because the warehousing and ordering costs are difficult to calculate and divide for single items, especially when there are a lot of items in the warehouse and the warehousing costs vary a lot between different items. Hence, the calculated order quantity is always an approximate value because the values used in the formula are usually based on estimates and average values. (Salmivuori 2010, 53) According to Sakki (2014, 81) the theoretical EOQ model can be utilised when optimizing the order quantities and hence aiming at reducing the amount of order transactions, but it should be kept in mind that in the end transportation costs have the biggest effect on the batch sizes. In addition, using the EOQ model can in some cases result in higher order quantities i.e. purchases are made less frequently but in bigger lot sizes. This is due to the fact that in cases where the demand is very high, it is more economical to buy in bigger lot sizes so that purchase order does not have to made so frequently. (Sakki 2014, 89)

3.2.2.2 Economic order interval (EOI)

The economic order interval (EOI) is based on a so-called periodic inventory system. This means that the inventories levels are reviewed periodically e.g. daily or weekly, and not continuously, and therefore purchase orders are made at regular intervals over the time. In this model, the order quantity is determined separately at each order time and determined based on how much the item has been consumed from the inventory since the last order. Therefore, the replenishment order quantity is always made so big that the present inventory level is brought up to the maximum inventory level. (Tersine 1988, 135-136) The formula for calculating the economic order interval for single items is presented below:

$$EOI\ (T) = \sqrt{\frac{2C}{RFP}}\ (in\ years)$$

In the formula, C = order cost per order, R = annual requirement for item, F = annual holding cost as a fraction of purchase cost and P = purchase cost of an item. After the economic order interval (T) has been calculated, it is possible to calculate the maximum inventory level (E) with the following formula:

$$E = \frac{R * (T + L)}{N}$$

In the formula N represents the operating days in years. All in all, EOI is useful when the orders from a company's different business units are combined for a single supplier in order to achieve bulk discounts and save in transportation costs. (Johnsson 2008, 273) Moreover, it is possible to count the EOI for multiple items and combine all the items to the same order, and thereby aim at increasing the total annual costs (Tersine 1988, 139).

3.2.3 Probabilistic inventory models in independent demand systems

The previous chapter presented deterministic inventory models, where the used parameters and variables are known or they can be calculated with certainty. However, the used parameters such as demand and lead times are not usually possible to determine as exact and continuous values because they usually have variability. When the parameters are treated as random variables, they are called probabilistic or stochastic. The main difference between deterministic and probabilistic models is that the probabilistic models takes into account risk and uncertainty and the probabilistic models are based on probabilities, distributions and standard deviations. (Tersine 1988, 184) In the real world the situation is rarely the same as in *Figure 5* in the previous chapter. A realistic inventory model is presented in *Figure 6*, taking into account that demand is actually discrete and irregular over time and therefore adding a safety stock (S) can prevent the company from stockouts.

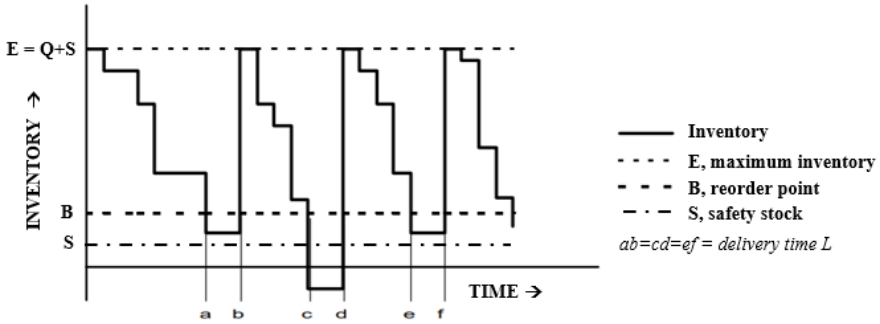

Figure 6. The realistic inventory model (Tersine 1988, 186)

Safety stocks and thereby reorder points can be defined in two different ways in a fixed order size system. The first way is to calculate the safety stocks with the help of known stockout costs. The second way is used when stockout costs are not known and the safety stock is calculated with the help of a specified service level, that is based on some probability distribution of demand during the lead time. (Tersine 1988, 189)

3.2.3.1 Safety stock (S)

Usually inventories are divided in cycle stocks and safety stocks. Cycle stocks are that part of inventories that is with certainty consumed from the warehouse by the next party of the supply chain. Safety stock on the other hand is that part of inventories that is very unlikely to be consumed from the warehouse but when consumed, it is consumed for true need. However, this division into cycle stocks and safety stocks is reasonable to do only in a logical way, because it is not reasonable to hold the safety stock separate from the cycle stock and therefore cause their obsolescence in case the safety stock is never consumed. (Karrus 2003, 36) The main objective of safety stocks is to avoid stockouts. In order to calculate the safety stock, the company must know the probabilities of different demand variations, holding costs for the inventory and stockout costs. The optimal safety stock minimizes yearly stockouts and holding costs of the inventory. (Horngren et al. 2009, 729-730) According to Tersine (1988, 184) safety stocks, unlike cycle stocks, are not usually determined by lot sizes, but they are rather determined directly from forecasts and therefore safety stocks protect against higher than expected demand levels.

In deterministic models, the reorder point (B) is calculated by simply multiplying demand (D) with lead time (L). In the probabilistic models, the safety stock (S) is added into the equation in order to protect against stockouts after the reorder point is reached and prior the replenishment order is received. According to Horngren et al. (2009, 729-730) a reorder point that takes into consideration uncertainty, can be calculated as follows:

$$B = DL + S$$

The safety stock in the equation above can simply calculated by decreasing the cycle stock from the total stock. However, according to Sakki (2014, 84) in practice purchase orders are usually being made in economic order intervals, because then all items that have gone below the reorder point and purchased from the same supplier can be purchased with joint orders in order to save in transportation costs. Therefore, the reorder point must be increased so that the stock is sufficient over the review and lead time. The order quantities can in this case be calculated with the EOQ model. The reorder point when using the EOI-system can be calculated as follows:

$$B = D\left(L + \frac{T\ (EOI)}{2}\right) + S$$

Probabilistic models usually include statistical considerations such as distributions and standard deviations. According to Tersine (1988, 191) the most used are the normal distribution, Poisson distribution and negative exponential distributions but the right distribution should be decided by the demand situation. For example, when demand is normally distributed, the reorder point can be calculated with the following formula:

$$B = \bar{M} + S = \bar{M} + Z\sigma = reorder\ point\ in\ units$$

In the formula $\bar{M}$ represents the average lead time in units and S is the safety stock in units. The safety stock in this formula can be calculated by multiplying the standard normal deviate (Z) with the standard deviation of lead time demand (σ). (Tersine 1988, 192) However, Tersine (1988, 191) emphasize that standard distributions in inventory analyses are applicable in theory but in practice they should not be employed in inventory analysis merely for their computational efficiency.

3.2.3.2 Service level

Service level is the measure used to quantify a company's market conformance. It is usually related to the ability to satisfy a customer's delivery date, for example, indicating the percent of all orders that have been sent on time or before the promised delivery date. Basically, service level tells how much of the demand can be instantly delivered from the warehouse to the customer i.e. the probability for no stockouts during the replenishment lead time. (Simchi-Levi 2003, 254) Service level is typically measured as a ratio or percentage value and is simplified calculated as follows:

$$Service\ level = 1 - Probability\ of\ stockout\ (demand > order\ point) = 1 - P\ (D > B)$$

The fundamental objective of inventory management is to maintain adequate service level with minimum inventory and administrative costs (Huiskonen 2001, 126). What the adequate service level is, is however determined by various factors. Usually the estimated stockout costs determine the adequate service level for a warehouse or a specific item and hence also determine the need of safety stocks (Schneider 1981, 615). Those items with high stockout costs on the other hand can be identified with the help of an ABC-analysis and for these items an acceptable risk of stockout should be determined (Lysons & Farrington 2006, 326). According to Huiskonen (2001, 125) spare parts usually must have a higher service level because the effects of stockouts can be financially significant, the demand of spare parts can fluctuate a lot and it can be very hard to forecast, and individual spare parts can be very expensive. It should be noted that the desired service level is the most difficult to meet just before the replenishment for the inventory is received i.e. when only the safety stock is remaining in the stock. Hence, the safety stock should always be so big that the desired service level is achieved also when operating with the safety stock. (Tersine 1988, 187) Therefore, the reorder points and safety stocks developed under different service levels will be different (Tersine 1988, 212). Eventually, the fundamental problem with service levels are that they exponentially impact the stock value i.e. the higher the desired service level, the higher the average inventory levels and hence also the inventory costs. This is demonstrated in *Figure 7* below.

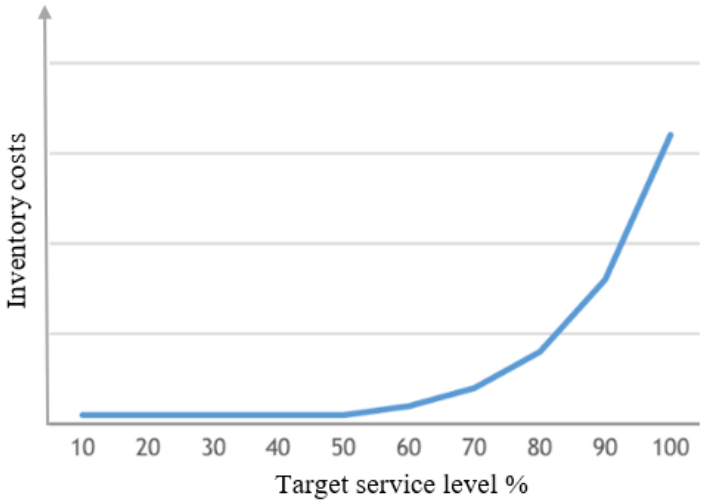

Figure 7. The exponential relationship between the service level and the inventory costs. (Adapted from Logistiikan maailma 2020)

The first thing in determining the safety stocks based on service level is to decide the desired service level. According to Karrus (2003, 36) the decision of the service level should be based on considerations of what is economically a sensible amount for the safety stock. If the service level is decided without taking into account the costs of the up keep of the service level, the decision can become very expensive for the company. For example, increasing the service level from 85% to 90%, may not cost so much, but when the service level is increased to 99%, the costs increases drastically because the safety stock levels must be much bigger. However, for example in manufacturing organizations the service level usually must be up to 100% because if the needed parts cannot be provided, the production can be jeopardized. Therefore, in manufacturing organizations the MRP system is usually a better way to control inventories than a fixed order size system. (Tersine 1988, 212)

Service Level Agreements (SLAs) are used for determining the desired service level and how services should work between two partners in cooperation. Usually SLAs are not separated from the original contract, but it is included in the outsourcing contract. (Lysons & Farrington 2006, 506) This is usually the case in VMI-contracts, where the SLA is an important part of the actual VMI-contract. (Zammori et al. 2009, 169)

3.3 Spare parts inventory management

In industrial environments, spare parts are used a lot for both maintenance and as normal consumables. The spare parts inventory management differs from traditional inventory management in several ways. Firstly, the service level must be higher for spare parts because in case of stockouts the effects can be financially remarkable. Secondly, the demand for spare parts can vary a lot and the fluctuations are hard to forecast. Thirdly, individual spare parts can be very expensive. (Huiskonen 2001; Molenaers et al. 2012; Roda et al. 2014) According to Karrus (2003, 36) spare part inventories actually resemble more safety stocks than traditional stocks. Furthermore, the management of spare parts is usually considered as a special case of traditional inventory management constituting of special characteristics such as remarkably minor demand volumes (Huiskonen 2001, 126) Also, it is extremely difficult to forecast the demand for spare parts and if the demand is extremely minor, the risk for obsolescence is high due to their specific functionalities (Dekker et al. 2013, 536). Moreover, Roda et al. (2014, 530) have pointed out that spare parts are usually sourced from one or a few suppliers, which causes limitations to purchasing lead times and costs. Eventually, if all spare parts would be available within one day in all circumstances, the management of spare parts would not be so difficult (Dekker et al. 2013, 537).

The immediate availability of spare parts is one of the most critical things when trying to shorten the downtime when a breakdown occurs. Therefore, companies tend to hold large quantities of spare parts in their inventories for immediate disposition in case they are needed. However, holding large inventories is limited by the availability of storage space and costs of holding inventories. (Braglia et al. 2004, 55) This is the usually the fundamental problem in companies, while different departments have differing opinions of what are the important parts that should be kept in the warehouse. From the maintenance perspective the most important parts are usually different than from the viewpoint of inventory or logistics management. Therefore, it is important that the company reaches a consensus between the two contrary goals. (Molenaers et al. 2012, 570; Roda et al. 2014; 531)

The primary objective of spare parts inventory management is to ensure that the required spare parts are ready and available when needed, in the right place and as low costs as possible. According to Sarmah and Moharana (2015, 456) many companies have thousands of spare parts in their warehouses and the spare parts are usually not appropriately

categorized on the basis of management attention. Therefore, the items in the company warehouse require a proper classification in order to manage the large number of the stock items. After the stock items have been classified into different categories, different ordering policies can be applied for each category and hence the stock items e.g. spare parts that fall to the same group, can be easier managed in the same way (Molenaers et al. 2012; Sarmah & Moharana 2015). Huiskonen (2001, 126) argue that although computers enable prominent mathematical modelling to optimize inventory investments and service levels, companies still need to consider how administrative efficiency can be improved. The improvement of administrative efficiency is usually conducted by item classification. In general, the classification models for spare parts can be divided in three different types; (1) quantitative (e.g. ABC-analysis), (2) qualitative (e.g. VED-analysis) and multicriteria analyses (e.g. AHP). These classification models are next shortly presented in their own sub-chapters.

3.3.1 ABC-analysis

The ABC-analysis is the most well-known and probably the most widely used classification method in companies worldwide. The ABC-analysis is based on the Pareto-principle, whereas it is a quantitative analysis tool based on economic measures. It is easy to use, but it is rarely suitable for spare parts due to its one-dimensional classification. As a one-dimensional analysis, it is best suitable for materials that are pretty similar and differ from each other mainly by demand volume and unit price. (Huiskonen 2001, 126) Also Molenaers et al. (2012, 570) argue that the ABC-analysis is still the most used spare part classification method in industrial companies, although there are more suitable theoretical models for spare parts classification available.

The traditional ABC-analysis is based on the Pareto's law i.e. the 80/20 rule. The Pareto's law indicates that 80% of a company's sales generates from 20% of the product line items. The 80/20 ratio is rarely exact and neither does it have to be, but it should be noted that the correlation is closer to 80/20 ratio than to 50/50 ratio. (Ballou 1992, 56; Sakki 2014, 62) Although the 80-20 rule indicates that there are only two classes, in practice the ABC-classification consists of several item classes. The items can be classified in A-, B- and C-classes or in more. Sakki (2014, 63) for example has introduced a five class model, where A-classified items represent the first 50% of cumulative sales or consumption, B-classified

items next 30% of the sales or consumption, C-classified items the next 18% of the sales or consumption, D-classified the last 2% of the sales or consumption and E-classified the items with no sales or consumption. How much items are in each class and how much their cumulative usage value is, is up to the company but the basic idea of the ABC-analysis is demonstrated in *Figure 8.*

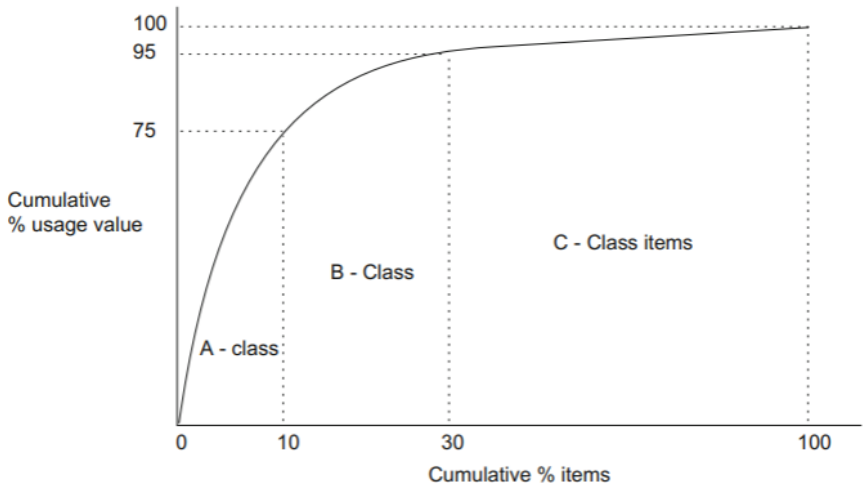

Figure 8. The ABC curve (Vrat 2014, 41)

Basically, the idea is that the inventory turnover of the items in A- and B-classes should be fast because those items tie up the most capital. If the inventory turnover of the items in classes A and B are slow, the replenishment lot sizes should be decreased. On the contrary the items in C- and D-classes can have slower inventory turnover ratios and they can be replenished in bigger lot sizes, but if the company has a huge amount of items in classes C and D, the company should clear out is it reasonable to store all of them in the company's own warehouse. (Ritvanen & Koivisto 2006, 39) According to Molenaers et al. (2012) in the ABC-analysis the items are ranked based on only one criterion, e.g. demand value or consumption but despite of the used criteria, the A-classified items needs close managerial attention while their value is so significant proportion of the total inventory value. Also Ritvanen and Koivisto (2006, 39) note that the A-classified items should be controlled efficiently and the company should strive to shorten their lead times. The basic idea in the ABC-analysis is that the items in the A-class are managed efficiently and more time can be used for controlling these items, while the items in the C-class can have lower service levels and their control should require as less time as possible.

Regardless of the broad adaption of the ABC-analysis in companies as a tool to enhance the inventory management, it is rarely a suitable control tool for spare parts. According to Huiskonen (2001, 129) this is mainly because the ABC-analysis does not take the criticality of the spare part into account. In spare parts the stockout costs of a critical part can be a multiple of its commercial value. Also, Roda et al. 2014, 533) have pointed out that although the ABC-analysis is seen as the classical classification tool, it rarely is able to provide a decent classification in practice. According to Braglia et al. (2004, 57) the ABC-analysis can be applied for spare parts classifications for example by dividing the items in three criticality classes: (A) very important, (B) important and (C) less important. However, for example Flores et al. (1992, 72-73) have introduced a multicriteria ABC-classification model that is more suitable for spare parts. In this model two classification criteria are used and the items are classified with the help of a joint criteria matrix (*Figure 9*).

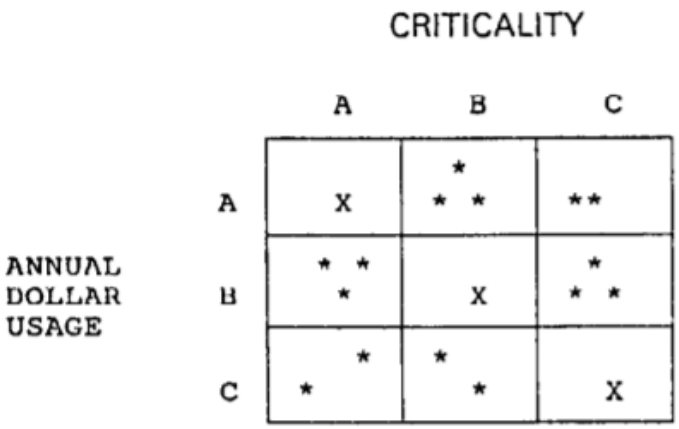

Figure 9. Multicriteria ABC-classification (Flores et al. 1992, 73)

In the model in *Figure 9* the items are classified in AA, BB or CC categories (the diagonal cells i.e. the X's) and in sub categories e.g. AB, AC, BA, BC, CA and CB (the off-diagonal cells, i.e. the *'s) based on their annual usage in euros and their criticality.

3.3.2 VED classification

The VED analysis is a commonly used qualitative classification tool for spare parts. The VED analysis aims at analyzing what happens if the items are not available when needed by categorizing the items in V (vital), E (essential) and D (desirable) items. The items in the V-class have extremely high stockout costs and they are vital for the continuity of the

production and therefore, the risk of shortage for these items should be extremely minor. The items in the E-class have significant stockout costs but they are not so vital for the production as the V-classified items. For the E-classified items shortages in the availability are a little bit more acceptable. The D-classified items have a minor impact on the production and their stockout costs are low, and hence a higher risk of shortage is tolerated for these items. (Roda et al. 2014, 532; Vrat 2014, 43)

The VED analysis can be utilized when determining the desired service levels for the items and thereby estimating an appropriate amount of safety stock to achieve the desired service level (Vrat 2014, 43) However, according to Roda et al. (2014, 533) the VED analysis have been criticised due to its lack of hard data in the criticality evaluation. In this model the criticality or importance of the item is based on the evaluators, e.g. engineers, materials managers, quality control staff or other persons, subjective evaluation of the item's importance and thereby there may be disagreements of the item's true importance. Moreover, also this model is based on only one classification criteria and it does not for example take into consideration how expensive the item is and how much its inventory holding costs are, and what are the lead times from the suppliers.

3.3.3 Multicriteria classification

Due to the high requirements for service levels and financial resources involved, and the very different characteristics of spare parts, encourages to use multicriteria classification approaches (Huiskonen 2001; Molenaers et al. 2012) In the previous academic literature many different criteria, e.g. inventory cost, item criticality, availability of spare parts in the market, essentiality, price, efficiency of repair, lead times, machine failure and supplier reliability, have been used as criteria to classify spare parts, but according to Huiskonen (2001, 129) the most relevant control characteristics for maintenance spare parts are usually criticality, specificity, demand and value. These four control characteristics and ways to assess them in multicriteria classifications are presented in *Table 1*.

Table 1. Four relevant control characteristics in multicriteria classifications

Control characteristic	**Assessment**
Criticality	Item criticality is widely used as a control characteristic in spare parts classification but there is no consensus of how it should be measured. Often the criticality is assessed on the basis of how big the impact of item shortage is on production, safety and environment. (Molenaers et al. 2012, 571) Theoretically, criticality can be assessed based on the downtime costs and in practice the criticality can be assessed based on a few degrees of criticality. The criticality can also be divided in: 1. Process criticality (the consequence item shortage has on production loss) and 2. Control criticality (ability to control availability of the item). (Huiskonen 2001)
Specificity	The specificity is usually assessed based on whether the spare part is a standard part or a user-specific part. *Standard parts* are used by many users and therefore there usually a lot of suppliers for these parts and hence the availability is usually good. For *user-specific parts* the availability is usually weak and suppliers are unwilling to keep these in their warehouses, and therefore the responsibility of availability and control is on the user of the parts. (Huiskonen 2001)
Demand	This characteristic is assessed based on demand volume and demand predictability of the item. Spare parts usually have low and irregular demand and as a classification criterion, the company should evaluate how much the item is consumed and how much it is needed. (Huiskonen 2001)
Value	Based on the value of the item, the company can make decisions of whether to store the item in its own warehouse or not. Especially for low price items, the replenishment arrangements must be efficient in order to keep the administrative costs in minimum. (Huiskonen 2001)

Especially one multicriteria classification model was widely studied in the literature; the Analytical Hierarchy Process (AHP). It utilizes both qualitative and quantitative criteria in the spare parts classification and it is able to assign weights for different parameters in cases where the importance for all criteria is not the same. (Braglia et al. 2004; Molenaers et al. 2012, 572; Roda et al. 2014, 535) However, according to Molenaers et al. (2012, 571) the AHP model is often considered as a too theoretical model and therefore the company management rarely agrees on using this model. The AHP approach has also been used as a

base for many other multicriteria classifications. For example, based on the AHP model Molenaers et al. (2012) developed a multicriteria classification model to evaluate spare parts criticality. In the model the criticality of the item was evaluated with the help of five different parameters: (1) equipment criticality, (2) probability of failure of the item, (3) replenishment lead time, (4) number of potential suppliers available and (5) maintenance type. On basis of these evaluations, the items are classified in four criticality classes: high, medium, low, no. Huiskonen (2001, 132) on the other hand have introduced a more practical model than the AHP for spare parts categorization and determination of respective policies for each category. The model is presented in *Table 2*.

Table 2. Categorization for spare parts and respective policies and strategies (Huiskonen 2001, 132)

		Criticality	
		Low	High
Standard parts	**Value** Low	• Simple order procedures e.g. with automated orders	• Use decentralized safety stocks and order in big quantities
		• Outsource control of inventories to a supplier	
	High	• Push inventories back in the supply chain	• Optimize user's safety stock (for high and smooth demand)
			• Ensure fast availability from a service company (for lower and irregular demand)
			• Utilize co-operative stock pools with several users' (for very low demand)
User-specific parts		• Hold own safety stocks and use partnerships with local supplier in order to ensure short lead times, increase dependability and to be the first priority for the supplier in emergency situation	
		• Standardize the spare parts if possible in the long run	

The basic idea in the model in *Table 2* is that the lower the value of the spare parts is, the simpler the replenishment policies should be and while the value is low, the replenishment quantities can be quite big. Also vendor managed inventory models can be utilized for spare parts when their criticality and value are low. When the criticality and value are high, the

availability of the spare part should be secured either by holding adequate safety stock, ensuring fast availability from a service company or creating co-operative stock pools with other users. (Huiskonen 2001, 131-132)

Of course, doing a multicriteria classification for all of the company's items can be extremely time consuming, while there can be thousands of items in the company's inventories. Therefore, Braglia et al. (2004, 57) argue that classification process should start with a simpler, one-dimensional criticality analysis (e.g. VED analysis) in order to identify the most critical spare parts for further analyzation. After that a more specific, multicriteria analysis can be conducted for the most important items.

3.4 Inventory performance measures

The performance of inventories can be measured with different ratios. This chapter focuses on discussing the inventory performance measures from the viewpoint of what is relevant to this study. The inventory ratios used to measure the overall performance of the inventories varies slightly considering the type of inventory. For example, if the items that have been consumed from the warehouse by selling them to customers, the inventory performance measures differ slightly from those used when the inventories are raw materials or spare parts, and the items have been consumed from the warehouse to manufacture the final product. Next three inventory performance measures are presented.

3.4.1 Inventory turnover

The most commonly used parameter for measuring how effectively current assets i.e. inventories are used, is inventory turnover. It is calculated by dividing yearly consumption with the average value of inventories (Sakki 2014, 55). Basically, this parameter shows how many times the company has used and replaced its inventory during a given period. The formula for calculating inventory turnover is presented below:

$$Inventory\ turnover = \frac{yearly\ consumption}{average\ inventories}$$

Inventory turnover can be calculated by using either units that indicate the physical number of pieces, weight or volume, or by using financial values (Ritvanen & Koivisto 2006, 36) However, it should be noted that the basis of calculation should be the same for both the consumption and inventory value when calculating inventory turnover by using financial values. If the yearly consumption is calculated by using sales with sales margin and the average value of inventories is estimated as purchase price, the inventory turnover values are reasonable to compare only if the same basis of calculation is used in all of the inventory turnovers that are compared with each other. The inventory turnover formula can also be used for calculating the turnover for a single item by using consumption and inventory measured by the number. Calculating the average value of inventories can be challenging or impossible, while the amount of current assets is constantly changing. Therefore, the inventory turnover is usually calculated by using the present value of the inventories. (Sakki 2014; 55)

According to Billesbach and Hayen (1994, 64) the inventory turnover ratio is a relatively reliable and accurate way of measuring inventory management performance, because it is not drastically affected by changes in price levels of raw material, component parts and finished goods, which are affecting the value of the inventory. However, according to (Tersine 1988, 17) concentrating on inventory turnover might result in higher unit costs due small and more frequently made purchases. Correspondingly, concentrating on low unit costs results in larger quantity purchases and hence reduces inventory turnover. Furthermore, the higher the inventory turnover is, the less capital is tied up in inventories and by doubling the inventory turnover it is possible to halve the costs of inventory (Hokkanen, Luukkainen & Karhunen 2014, 205). Increasing the inventory turnover is however according to Hokkanen et al. (2014) meaningful only to up to a certain point. For example, increasing the inventory turnover from two to three has a significant effect on costs, while increasing the inventory turnover from eight to nine hardly affects the costs at all. Hence, while considering inventory turnovers, it is reasonable to find an inventory turnover that is suitable for the company and its operations.

3.4.2 Days of inventory

Inventory turnover can also be measured in time. The days of inventory ratio or inventory turnover time describes how long the inventories last with average consumption or in other words how long the inventory is staying in the warehouse before it is consumed. (Sakki 2014, 56) Days of inventory is sometimes also referred as days sales of inventory (DSI) or days inventory outstanding (DIO). The formula for calculating days of inventory is presented below:

$$Days\ of\ inventory = \frac{365}{inventory\ turnover}\ (d)$$

The days of inventory can in some cases be easier to assimilate than inventory turnover, while it basically measures how many days capital is tied up in inventories (Sakki 2009, 76-77). For example, if inventory turnover is twelve, the days of inventory is approximately 30 days, meaning that the inventory is tying up capital for 30 days before it is consumed from the warehouse.

3.4.3 Inventory to sales

Inventory turnover and days of inventory are practical when measuring the inventory management performance inside the company. When the aim is to compare inventory values between companies, inventory to sales ratio is practical because it proportions the amount of inventory to the turnover of the company (Sakki 2014, 56). The inventory to sales ratio is calculated as follows:

$$Inventory\ to\ sales = \frac{value\ of\ inventory}{total\ revenue}\ (\%)$$

The inventory to sales ratio varies a lot between different industries and over time. For example, a study conducted by Irvine (2003) showed that inventory to sales ratios have been in a downtrend in the US mainly due to the adoption of JIT and other inventory control systems in the early 1980s. The inventory to sales ratio is also highly affected by the industry. *Table 3* demonstrates the average inventory to sales ratios on different industry sectors in Finland.

Table 3. Current assets on some of the industry sectors in Finland in 2012. (Adapted from Sakki 2014, 56)

	Value of inventory (in million euros)	**Inventory to sales (%)**
C Manufacturing	13 849	10,2 %
10 Manufacture of food products	788	7,9 %
16 Manufacture of wood and of products of wood and cork	750	11,8 %
17 Manufacture of paper and paper products	1555	10,7 %
20 Manufacture of chemicals and chemical products	852	10,6 %
25 Manufacture of fabricated metal products	857	12,3 %
27 Manufacture of electrical equipment	592	12,5 %

3.5 Supply chain collaboration

Inventory management policies can roughly be divided in keeping own inventories and inventories owned by the supplier. Inventories owned and managed by the company itself usually follow the traditional order-to-delivery process (OTD), according to which the purchasing process contains four sub-processes: customer's order, supplier's delivery, transportation by the logistics service provider and the customer's product receipt sub-process (Forslund, Jonsson & Mattsson 2009, 41). An alternative for keeping own inventories is to outsource the management of inventories either completely or partially so that an external party takes care of the storing and availability of the inventories. According to Häkkinen et al. (2007, 10, 63) outsourcing of inventory management is becoming more common especially in the industry, because traditional purchasing includes a lot of administrative work and hence it is economically reasonable. The applicable technique in outsourcing vary greatly depending on the purchased products. At the moment, the trend in industrial companies is to outsource the procurement of maintenance, repair and operation items as well as C-classified items because of their big volumes and low unit prices. (Häkkinen et al. 2007, 10, 63)

Inventory management can indirectly be affected by supply chain management and it can be seen as an important part of supply chain management (Power 2005, 253). Lately, the traditional idea of separate purchasing and logistics functions have developed into supply chain management, which can be seen as a broader strategic approach to materials and distribution management (Tan 2001, 39). The supply chain integration can be characterized by information sharing, trust, cooperation, collaboration, partnerships, shared technology

and as a shift from the management of separate functional processes to managing integrated chains of processes. Especially the collaboration theme in supply chains occurs when the buyers and suppliers establish close partnerships and hence manage to reduce inventories, shorten lead times and improve customer service. (Power 2005, 253)

The objective of supply chain management (SCM) is to deliver items on time in the right place as requested so that the customer demand is fulfilled. To meet this goal, members in the supply chain must communicate with each other properly. The key for effective communication is a well-structured information sharing policy, according to which information of forecast, sales revenue, demand variation, inventory, production plans etc. should be shared. (Nimmy et al. 2019, 537-538) Cachon and Fisher (2000, 1032-1033, 1042) argue that significant reduces in supply chain costs can be achieved when the buyer fully shares the information of its inventory data. In practice the supplier can exploit this full information to improve order quantity decisions and allocation decisions. Nimmy et al. (2019, 538) define this information sharing of sales data, estimation of forecast and planning of demand in supply chains as *supply chain collaboration (SCC).* Supply chain management has in recent decades adopted many new collaborative techniques such as just-in-time (JIT), vendor managed inventory (VMI), collaborative planning, forecasting and replenishment (CPFR) and orchestrated supply chain. The evolution of collaborative supply chain management is demonstrated in *Figure 10*.

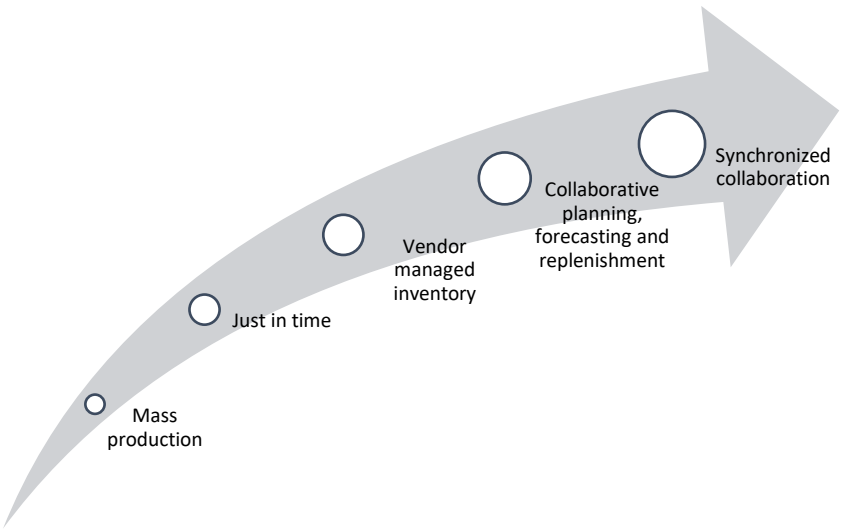

Figure 10. Evolution of supply chain collaboration (Nimmy et al. 2019, 538)

Obviously, outsourcing the management of inventories requires supply chain collaboration. At the end of the 20th century companies used widely just-in-time and lead production approaches as a strategy to improve their performance. Now, companies are increasingly building competitive advantage through supply chain collaboration. (Cao et al. 2010) According to Derrouiche, Neubert and Bouras (2008) the importance of supply chain collaboration as a part of the strategic planning in companies and as a way to create competitive advantage has increased continuously. Closer relationships with suppliers are acknowledged as an opportunity to achieve cost reductions and increase revenues as well as a tool to increase flexibility in dealing with supply and demand uncertainties (Bowersox et al. 2000). Derrouiche et al. (2008) have identified quick response (QR), continuous replenishment program (CRP), vendor managed inventory (VMI), collaborative planning, forecasting and replenishment (CPFR), rapid replenishment (RR) and centralized inventory management (CIM) as commonly used collaborative supply chain strategies by companies. The most relevant supply chain collaborative techniques for this thesis are next discussed in their own subtitles. These techniques have been chosen because they are the most suitable for the case company needs.

3.5.1 Just-in-time philosophy

The *just-in-time (JIT) philosophy* is based on the attempt to match demand with supply. The basic idea is that when it's perfectly working, the deliveries can be deployed at just the right time. The JIT philosophy aims at increasing the quality of products and eliminating waste by purchasing in small lot-sizes only to true need. Purchasing in small lot-sizes, only when the products are needed, leads in smaller inventories, lower levels of scrap and less time spent on inspecting the quality of the purchased goods. To make this small lot-size JIT purchasing work efficiently, the buyer and supplier must have a mutually beneficial, long-term, co-operative relationship. (Banerjee & Kim 1995) The fundamental success of the just-in-time philosophy lies in reduced inventories of materials. Salameh and Ghattas (2001, 158) argue that the focus on reducing inventory levels, led to a situation where some companies adopted a mistaken notion that inventories have no value and hence, they should be totally removed, but even in just-in-time production usually a small buffer stock is required. However, according to Gunasekaran (1999, 78) JIT purchasing is usually characterized with

a small supplier base and the suppliers locating close to the buyer's plant. Therefore, more frequent, small lot-size deliveries can be made but on the other hand these long-term, collaborative relationships with the suppliers can make the buyer very dependent on the supplier and its frequent deliveries.

JIT is usually considered as a lean management tool, but actually the concept of JIT is starting to approach the *Lean philosophy*. The concept of JIT includes (i) product design, (ii) process planning, (iii) organization and people and (iv) production planning and control, and moreover as a bigger wholeness it consists of product standardization, using of modular product structures, shortening of lead times, smaller lot sizes and pull control. Separating this wholeness of the operations model of the *lean philosophy* is difficult and thus lean and just-in-time are commonly held as the same approach. Neither is it necessary to make a clear separation in the definition between these two approaches. (Lai & Cheng 2009, 9-13, 87) Additionally, Vrat (2014, 22-23) has argued that companies operating in uncertain supply environment, with variability in lead times usually prefer the *just-in-case (JIC)* approach instead of the just-in-time approach. In a just-in-case supply environment, companies maintain low inventories due to variability of lead times, whereas in a just-in-time environment with no uncertainty and deterministic demand and supply, companies prefer holding no or very low inventories.

The advantages of the close cooperation between the buyer and the supplier in the JIT environment include quality improvements, lowered inventory costs, sharing of technology and reduction of lead time (Yang & Pan 2004, 853). Gunasekaran (1999, 78) on the other hand has identified smooth flow of materials between the buyer and supplier, order cost reduction, stock reduction, improved quality and product simplification as advantages of JIT purchasing. Although, just-in-time has its pros regarding lowered inventory levels and less capital is tied-up in inventories, it also has its cons. First of all, JIT makes the company rather dependent on its suppliers. Also, ordering in remarkably small quantities is considered inefficient. Additionally, possible minimum order sizes of the supplier might cause problems while the buyer is forced to make bigger orders and therefore the just-in-time approach doesn't work as efficiently as it could be working. (Nimmy et al. 2019, 539) Nevertheless, according to a study conducted by Billesbach and Hayen (1994) JIT was proven to have statistically significant improvement in inventory management performance and furthermore in overall financial performance of companies. Moreover, findings of a study conducted by

Biggart and Gargeya (2002) indicate that JIT-adoption actually substantially reduces the inventory to sales ratio on a statistically significant level.

3.5.2 Vendor managed inventory

Vendor managed inventories (VMI) are literally inventories where the buyer outsources the inventory operations to the vendor i.e. the supplier has the authority to oversee product inventory levels on behalf of the buyer. (Dasaklis & Casino 2019, 50) VMI is based on a strategic partnership between the buyer and the service provider, and the fundamental objective is to ensure the availability of items at all times, in the right place and in the right lot sizes. The service provider for a VMI can be for example a producer, supplier or logistics operator. Regardless of the service provider, the basic idea is that the service provider administers the inventory levels nearby to the end-use location. (Häkkinen et al. 2007, 17-18) VMIs are based on collaboration and integration of operations between buyers and suppliers, which are mainly achieved by effective information sharing and business process reengineering. Information of sales and inventory levels at real time is usually shared with the help of information technologies e.g. electronic data interchange (EDI) or by changing XML-files over the internet. (Pasandideh, Niaki & Nia 2010) By establishing a mutually beneficial relationship between the buyer and the supplier, VMI aims at improving the overall supply chain performance. (Dasaklis & Casino 2019, 50)

The possession of the items in VMI's is not unambiguous. The stored items can be in the possession of either of the parties; either the buyer or the service provider, and is always based on the contract between the two parties. (Häkkinen et al. 2007, 18) According to Hines et al. (2000) it is typical that the buyer has committed to buy the whole inventory regardless of has it been sold or not, but the payment of items is discharged after the items have already been consumed. If the term of payment is for example 14 days net, the inventories might have been already consumed before the possession is juridically transferred to the buyer.

VMIs are typical arrangements in retail stores. In the industry sector, VMIs are mostly used for C-classified and MROs, i.e. maintenance, repair and operations items. These items are typically cheap items used in maintenance, or other non-critical items that can be bought in bigger order quantities e.g. office supplies and papers. (Häkkinen et al. 2007, 10) However,

according to Ellinger et al. (1999) in the academic literature, big volumes are usually considered as a prerequisite for a successful VMI. Häkkinen et al. (2007, 19) on the other hand argue that VMIs can also work successfully with lower volumes, when the supplier and buyer have optimized the operations according to their own requirements. In these cases, VMIs are applied for items where the volumes are not big and the inventory turnovers are relatively low.

When compared to traditional ordering process between the buyer and the supplier, VMI offers the opportunity to eliminate duplicate functions between the buyer and the supplier, delays in deliveries, out-of-data merchandise and much more (Lai & Cheng 2009, 90). Basically, the benefit for buyer is that it doesn't have to make purchase orders which reduces both operating and administrative costs. As for the supplier, the benefits appear as better demand forecasting which in turn has an effect on the accuracy of inventory management. (Dasaklis & Casino 2019, 50) According to a survey made by EY (2016, 17) especially large companies have achieved significant improvements in inventory performance and working capital management with vendor managed inventories. However, this can be explained by the fact that vendor managed inventory arrangements are more likely to be used among large companies with high inventory volumes rather than among small and medium sized enterprises (SMEs).

3.5.3 Continuous replenishment program

Continuous replenishment program (CRP) is a type of vendor managed inventories, where the supplier is responsible for maintaining the buyer's inventory levels on a predetermined level by taking care of material resource planning and replenishments. Basically, it is a restocking process used to make the purchasing process between the supplier and buyer more efficient, by eliminating purchase orders. (Derrouiche, Neubert & Bouras 2008, 429) In this program the supplier visually maps the inventories in the buyer's premises and takes the item shortages into consideration. Inventory replenishments are made as often as needed and as determined in the contract, usually once or twice a week. In order to avoid excessive work, the shortages are always mapped at the same time as replenishments are made. The possession of the items is transferred to the buying company when the supplier has placed the items on the shelf. (Hines et al. 2000)

3.5.4 Consignment stock

Consignment stocks (CS) are innovative approaches for supply and inventory management, where the buyer and supplier establish a mutually beneficial continuous collaboration, and both parties have equal gains (Battini et al. 2010). The fundamental idea in CS policy is that the supplier ensures that the inventory levels are always between the agreed minimum and maximum level in the stock that is located in the buyer's plant and the buyer draws items from stock only when needed (Valentini & Zavanella 2003, 216). This way of operation changes the cost structure of both the buyer and supplier. While in traditional procurement processes costs are caused for the both parties in forms of inventory holding costs and financial costs of the capital tied up in inventories, in the CS policy the stocking costs are buyer's responsibility because the inventories a physically located in the buyers premises, and the supplier sustains the financial costs of the capital immobilised until the buyer draws the item from the stock. (Battini et al. 2010) The difference in the cost structures between traditional purchasing and under CS policy is demonstrated in *Table 4* and *Table 5*, where h_{fin} represents the financial component of holding unit costs (h), and h_{stock} represents the stock component. The h_{fin} is the investment of financial resources in the production or purchasing of a product and h_{stock} is the warehousing costs of the item, e.g. stocking, handling and insurances. It should be noted that $h_{s,\ fin} + h_{s,\ stock}$ (supplier holding unit costs) is generally bigger than $h_{c,fin}+h_{c,stock}$ (buying company holding unit cost) because the financial component increases as it goes up the supply chain. (Valentini & Zavanella 2003)

Table 4. Relevant inventory costs in traditional purchasing

		Position of raw material	
		Supplier	Company
Relevant costs	Supplier	$h_{s,\ fin} + h_{s,stock}$	0
	Company	0	$h_{c,fin}+h_{c,stock}$

Table 5. Relevant inventory costs under CS policy

		Position of raw material	
		Supplier	Company
Relevant costs	Supplier	$h_{s,\ fin} + h_{s,stock}$	$h_{s,fin}$
	Company	0	$h_{c,stock}$

In the study conducted by Battini et al. (2010, 2078) it was discovered that savings from 20% up to 40% of the annual management costs can be achieved by setting up a consignment stock when compared to the traditional EOQ policy. The CS policy is applicable especially for consumables with low unit prices, high annual consumptions, small dimensions and are easy to store, such as metallic, electric and plastic fasteners, small parts, personal protection equipment (PPE) and small tools. Considering these items, the CS policy seems to be most beneficial and can work effectively even in situations where demand varies highly, there is risk for obsolescence and availability of space in the buyer's premises causes constraints.

As stated earlier, the CS policy is beneficial for the both parties. From the buyer's perspective, the biggest benefit is that it does not have to bear the financial costs i.e. tie up working capital to inventories. In addition, while the supplier maintains the inventory levels the buying company has always materials on-hand, lead times are eliminated and, administrative and managerial costs are reduced mainly because the company does not have to make purchase orders. From the supplier's perspective, the biggest benefit on the other hand is that it does not have to bear the warehousing costs of the inventories, while the items are physically in the premises of the buyer. In addition, the supplier is able to optimize its production lot sizes and transportation, it has more space available and it can achieve a long-term relationship with the buyer. (Battini et al. 2010)

4 RELEASING WORKING CAPITAL IN THE CASE COMPANY

In this chapter the results from the empirical part of the thesis are discussed. This part investigates the phenomenon in question within the case company's context. The aim in this part is to find solutions for the research problem and the current challenges the company faces within this subject. This section is started by doing a quantitative inventory data analysis of the current situation in the case company by collecting reports and statistical data from the enterprise resource planning (ERP) system. Also qualitative methods such as exploring, observation and interviews are used as research methods in this chapter.

4.1 Research methodology & data collection

The research methodology for this thesis is an action-oriented case study. The main objective is to find solutions to the research problem and to improve the problem. Action-oriented research approach is suitable when the aim is to understand a specific problem and find a solution for it by utilizing and combining historical data, appropriate theory and practice. (Olkkonen 1994, 74-75) Olkkonen (1994, 74-75) also state that the action-oriented approach is often used when an organization's management, operations, decision making processes and problem solving are studied. Moreover, according to Pihlanto (1994, 3) the action-oriented approach suits well for management studies with practical orientation. Fundamentally this thesis is a case study. In a case study intensive and detailed information of a specific case is examined. The aim is at describing a phenomenon by utilizing different research methods such as interaction and interviews, observation, analyzation of historical data and document research when collecting the information. (Hirsijärvi, Remes & Sajavaara 2007, 130-131) Characteristic for a case study is also that it intensively examines a situation in an organizational unit during a single time period, it provides profound information for the case entity and suggest hypotheses (Pihlanto 1994, 5). In case study context, also the research problem is usually researched, illustrated and explained mainly with the questions "How?" and "Why?" (Yin 1994)

The empirical part investigates the phenomenon in question within the case company context. The aim in this part is to find a solution for the research problem and the current

challenges the company faces within this subject. This section is started by doing a quantitative inventory data analysis of the current situation in the case company by collecting reports and statistical data from the enterprise resource planning system. The main tool for storing the data is an Excel spreadsheet, where all the stock item specific data collected from different information systems are merged with the help of the stock item number. In addition, qualitative methods such as exploring, observation and interviews are used as data sources in order get a deeper understanding of the phenomenon behind the collected data and analysis results.

Although this research includes aspects from both qualitative and quantitative research methods, the research is conducted as a qualitative research. It is typical for a case study that it uses both qualitative and quantitative methods, but fundamentally a case study is classified as a qualitative research (Yin 1994). The qualitative research methodology is the most reasonable when considering the subject and research questions of the thesis. According to Metsämuuronen (2011, 220) qualitative research is best suited when the interest is in the detailed structures of events and the goal is to understand the phenomenon being studied. Alasuutari (2011, 32) argue that it is quite challenging to define an absolute research methodology because qualitative and quantitative research have many common principles and they are often applied to the same research and analysis of the same research material. However, Metsämuuronen (2011, 220) state that relative to the research it is meaningful to choose one or the other as the main methodology depending on the research object.

4.2 Background of the case company

This thesis was conducted for a case company. The case company is a large manufacturing company. Due to the confidentiality of the used information, the company wishes to stay anonymous and therefore the company is not presented in more detail. Data and findings gathered from the used data sources are utilized so that the case company can't be recognized and no confidential information is revealed. The need for examining the means of inventory management to reduce the tied-up working capital in the case company have derived from the company noticing that the amount of working capital being tied up in inventories had increased. The company had also noticed that the amount of stock items in their ERP-system have continuously been increasing and therefore the management of the totality have become

more challenging. It also appeared that the company lacks common methods and instructions on how the inventories are managed and operations of how the amount of tied up working capital is monitored and managed in cooperation between different departments in the company.

The thesis is limited to studying the impact of consumables in the tied-up working capital. The consumables in this study consists of spare parts, repair parts i.e. tools used when repairing something, protective clothing and equipment, and some office supplies. Packing materials, raw materials, work in process and finished goods are not taken into account in this study. The study is limited to concern only consumables because it is possible to lower or change their inventory levels without directly harming the production levels or sales. The objective is to find out of which materials it is possible to lower inventory levels and how it can be done. The chance of moving some stock items entirely to vendor managed inventories is also considered, which obviously could help in releasing some working capital while the money would be tied-up in the supplier's inventory and moreover it would reduce administrative work. Another objective is to standardize and clarify the operation modes in the company, so that all employees operates alike and knows how things are done correctly, in order to prevent the inventory levels from increasing due to double work or lack of competence.

As mentioned earlier, the case company is a manufacturing company. Therefore, the company needs big inventories of spare parts for the maintenance of machines and other equipment. The mill services, consisting of the maintenance department and technical services, is responsible of several physical warehouses on the mill area, containing consumables for the needs of preventive maintenance, machine and device maintenance, and building maintenance. In this thesis, only the warehouses administered by the mill services are taken into consideration, although the company also has many warehouses for manufacturing items and raw materials, and for finished goods. The case company has 11 separate warehouse locations on the mill area and one rented warehouse outside of the mill area, which is administered by the mill services. Many of the warehouses on the mill area are physically in the same space next to each other or in different floors, but contain different items and are therefore defined as their own warehouses in the company ERP system. In addition, the company has some inventories, which are owned by the case company but are in the premises of suppliers and hence, for clarity reasons are defined as their own inventories

in the company ERP-system. All of the warehouses taken into account in this thesis are listed in *Appendix 1*. *Appendix 1* shows that in addition to normal warehouses managed by the case company, the company has five CRP-warehouses, four warehouses with just-in-time characteristics, one consignment stock, one vendor managed inventory and four warehouses where company owned items are stored in supplier's warehouse.

4.3 Inventory management in the case company

In this chapter the current state of inventory management in the case company is analysed. This part was mainly conducted by observing and discussing with case company representatives from different departments; the purchasing department, mill services and the finance department. When considering stock items, the purchasing department is responsible of making the purchase orders and creating the stock items in the company ERP-system. Mill services on the other hand administers the physical warehouses, decides which items must be in stock and defines stock item specific information considering e.g. reorder points, order quantities, suppliers and coverage group i.e. the ordering practices. The finance department takes care of warehouse book value and some internal reporting.

The management of stock items is mainly based on the predefined reorder points of each stock item in the company ERP-system. The basic idea is that when the inventory level is decreased to the reorder point, the stock item is ordered according to the predefined order quantity. The reorder point and order quantity for each stock item is defined according to mill service estimates of consumption and criticality or according to supplier package sizes. However, not all stock items are ordered always when they reach the reorder point. Whether the stock item should be ordered or not, is defined by ERP-system coverage group codes: ND, PD, PV and Z1, where ND means that the stock item is not ordered and the item does not rise to the material resource planning list, PD means that the item is ordered if needed, PV means that the item is either in a CRP-warehouse or in a consignment stock and is therefore not ordered, and Z1 means that the stock item is ordered when the reorder point is reached. Furthermore, the company has a material resource planner who approves the stock items that can be ordered by the purchasing department.

The purchasing department creates the stock items to the company ERP-system according to information provided by the mill services. The case company has recognized that there

are two fundamental problems in the creating of new stock items. Firstly, when the purchasing department gets the order to create a new stock item to the ERP-system, the creating of the stock item should have been accepted on higher level. This part however is often passed and the purchasing department does not make sure that the stock items have been approved. Secondly, the company lacks instructions of how the new stock item should be named in the ERP-system. The stock item number is defined according to running numbering from the ERP-system and hence the item should be named particularly clearly so that everybody can find the stock item from the ERP-system. Unclear naming of items increases the risk that the stock items are created as duplicate and therefore tying up double amount of capital.

4.4 Analysis of the warehouses

The empirical part started by doing an extensive analysis of the current state of the inventories in the case company. This phase started by listing both the physical warehouses and the warehouses in the company ERP-system and gathering information of them into one Excel file. By mapping the inventories, the goal was to provide a clear picture of how many warehouses there are in the mill area and supplier premises, where they are located, what they contain, what is the possession of the items in the specific warehouse and operating instructions concerning the specific warehouse. *Appendix 1* contains limited information of warehouse location, possession and what they contain. A more specific table with warehouse specific information was made for the case company utilization but was not included in this thesis due to confidentiality reasons. The company lacked a warehouse list that included general information and operating instructions of each warehouse and therefore much of the information was memory-resident and operating instructions for each warehouse was not clear for all.

The next phase in the inventory analysing process was to gather information of all the stock items in the company ERP-system into one Excel file. This was made by merging information and reports from different systems in the company with the help of the stock item number, but in some cases the information had to be searched item by item from the company ERP-system. The goal of this was to get an understanding of how big the different warehouses are and how much they contain items. The objective was to get a comprehensive

data of the stock items and connect reports utilized by different departments in the case company.

The final data of stock items contained information of suppliers, item categories, in which warehouses they are located, are they ordered according to normal material resource planning, inventory levels from January 2020, the financial values from the balance sheet from January 2020, are the items spare parts for how many machines, how old the inventories are, how much they were consumed during year 2019, what are the reorder points and order quantities. This data of stock items was done mainly for the use of this thesis but it could be utilized for various other development projects in the future, because that comprehensive list has not previously been made in the case company. For this thesis the data was mainly utilized for analysing the current state of the warehouses and for choosing the target warehouse for deeper inspection.

The case company inventories of consumables are relatively big. *Appendix 2* demonstrates how big the case company warehouses are and how much their financial value is on the balance sheet (January 2020). There are 21 975 different stock items in these warehouses and the total financial value is 5,9 million euros. The count of stock items tells how many different stock items there are in the warehouse but does not tell the individual amount of the stock items in the warehouse. *Figure 11* shows that working capital is mainly tied up in the biggest warehouses. Warehouse 4001 has the most different stock items and has a financial value of 1,4 million euros. Warehouse 4003 contains big spare parts and therefore ties up most working capital, 2,1 million euros, but on the other hand contains only 2096 different stock items. Warehouses 4010 and 4006 contains small spare parts, repair parts and protective clothing and equipment that has a low financial value but there must be a big variety of them and therefore there are relatively many different stock items in these warehouses. All in all, the working capital seems to be tied up in the biggest warehouses and the smaller warehouses have only minor or no financial value. Obviously, this can partly be explained with the fact that not all warehouses stock item inventory levels are maintained in the company ERP-system, but they have a stock item number in the ERP-system.

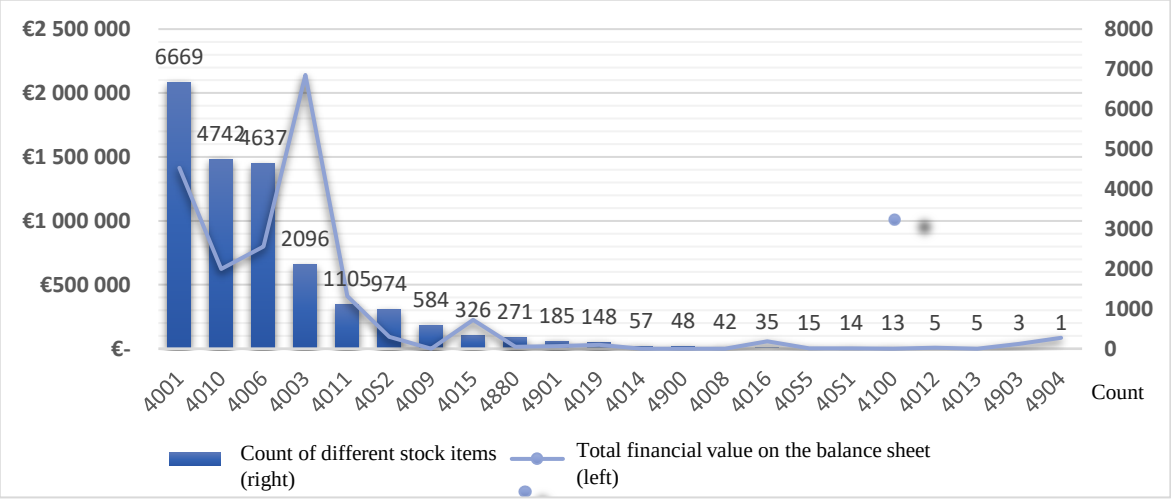

Figure 11. Size of the warehouses

In order to analyze the consumption of stock items in the case company, a graph demonstrating the overall consumption of all stock items in the specific warehouse was made (*Figure 12*). The overall consumption in the chosen warehouses was 1,96 million euros during the year 2019. *Figure 12* shows that the biggest consumption was in warehouse 4003, which can again be explained with the big spare parts being stored in it. The next biggest consumption seems to have been in warehouse 4010 (407 327€). This warehouse contains small maintenance items and protective clothing and equipment which have low financial value, and compared to the financial value the consumption is relatively big. Again, not all warehouses stock item inventory levels are maintained in the company ERP-system, but they have a stock item number in the ERP-system, which explains why so many warehouses seem to have zero consumption during the year 2019.

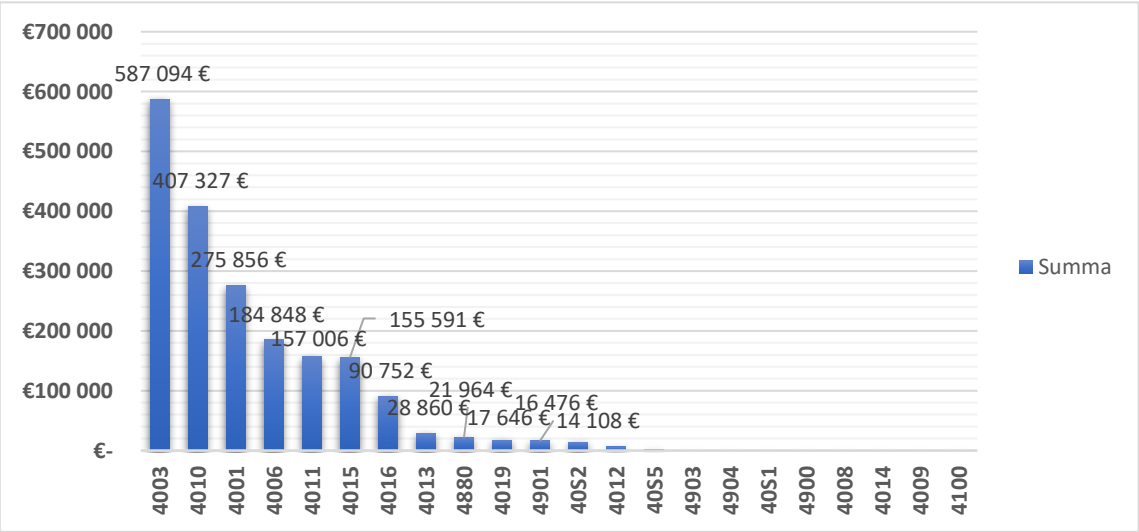

Figure 12. Consumption in euros from year 2019

In general, the case company inventories seem to be quite old. Of *Table 6* it can be seen that the case company has a little bit over 2 million euros tied-up in inventories that haven't been used in over four years. This means that the inventory turnover of these stock items is very slow and it can partly be explained with many big and expensive spare parts the company must always keep in its warehouse in order to secure the continuity of production. However, the company should clear out if there are other reasons for this i.e. if there are also unnecessary items that tie up lots of working capital.

Table 6. Inventory Obsolescence

Last consumption	Financial value on the balance sheet
Under 1 year ago	1 772 703 €
1-2 years ago	839 163 €
2-3 years ago	614 570 €
3-4 years ago	621 040 €
4-5 years ago	2 061 630 €
No information	56 411 €
Grand Total	**5 965 517 €**

Based on the warehouse analysis and discussion with case company representatives, warehouse 4010 was chosen as a target warehouse for this thesis. Firstly, because warehouse 4010 contains a lot of stock items but their financial value is low. Secondly, the stock items in warehouse 4010 are not so critical for the continuity of production and the delivery times of small maintenance items and protective clothing and equipment are usually fast, which means that there is a great potential that the inventory levels of these items could be lowered and it would be safe without jeopardizing the production. In addition, the CRP-warehouses were chosen for this thesis because they contain a lot of stock items that tie up case company's working capital but the company felt that the management of these inventories had become disorganized over time. Also, the CRP-warehouses are physically located in warehouse 4010 which made them a good target for further analysis.

4.5 Releasing working capital tied up in warehouse 4010

Warehouse 4010 contains small maintenance items, items for property maintenance, protective clothing and equipment, pipes and pipe links, bearings, cables, office supplies and much more. The warehouse contains 4742 different stock items and their total financial value

is 624 053 €. The consumption and purchases in euros are nearly even during the year 2019. Basic information of this warehouse has been gathered in *Table 7* in order to get an idea of how big the warehouse is.

Table 7. Basic information of warehouse 4010

Count of different stock items	4742
Financial value (January 2020)	624 052,72 €
Consumption (2019)	407 326,64 €
Purchases (2019)	449 150,75 €

Next the aim is to identify those item categories that have had the biggest consumption during year 2019. *Figure 13* shows those ten item categories that have had the biggest consumption during the year 2019 and the amount of capital that item category ties up. The total consumption of these ten item categories was 254 836€, which means that 63% of the total consumption in warehouse 4010 consists of these ten item categories. The exact values for both consumption and financial value are presented in *Appendix 3*. The biggest consumption comes from item categories 60802 & 60801 (protective clothing and equipment). Their financial value on the balance sheet is rather low and from this it can be concluded that these stock items have a rather high inventory turnover. From these items many could be moved to the already existing consignment stock because the supplier would probably be interested in it due to their high consumption. By doing this, the case company could release tied-up working capital because the consignment stock would tie up the supplier's capital. In addition, this would reduce the need to make purchase orders which again reduces both operating and administrative costs.

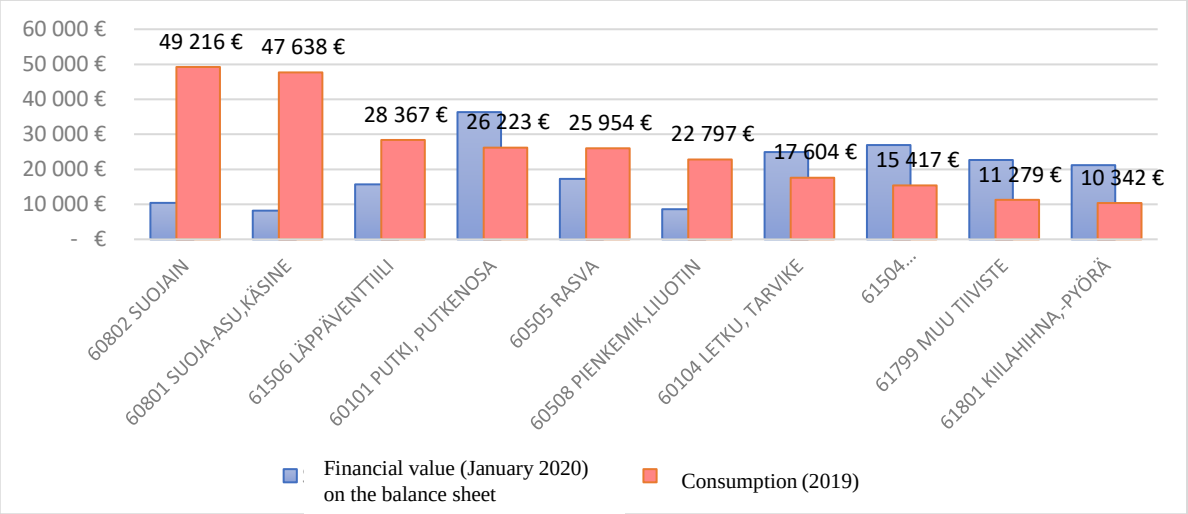

Figure 13. The ten item categories with the biggest consumption

Of the item categories in *Figure 13*, one supplier seems to be providing a lot of items in the item categories 60101 (Pipes and pipe links) and 61504 (Ball and segment valves). Both of these item categories tie up relatively much of capital. The total purchases to this supplier have been 39 168€ during the year 2019, mainly consisting of the two item categories: pipes and valves (*Appendix 4).* Therefore, the company could try to make an agreement of a consignment stock of the 547 stock items this supplier has been providing. This supplier has already shown interest in setting up a consignment stock for these stock items and with the data collected for this thesis, it is possible to identify all those stock items that could be transferred to this consignment stock. By doing this, the case company is able to lower the inventory levels of these stock items to zero in its own warehouses and therefore release working capital tied up in these inventories.

Next, the item categories are analysed from the viewpoint of how much their financial value is. *Figure 14* shows those ten item categories that have the biggest financial value in January 2020 and their consumption during year 2019. It can clearly be seen that these item categories tie up lots of capital but their consumption has been relatively low. The total financial value of these ten item categories is 330 468€, which means that 53% of all the capital tied up in warehouse 4010 is tied up in these ten item categories. The exact values for both the financial value and consumption of these ten item categories are presented in *Appendix 5*. The negative consumptions have resulted from the company adding stock items in the warehouse more than the consumption has been, for example in the yearly inventories or when old machine parts have been taken into the warehouse as spare parts. The fundamental idea is, that if the item category ties up a lot of capital, but the consumption is low, there could be a chance to lower both the safety stock and cycle stock. The company was provided a list of (1) those stock items where safety stock and cycle stock could be lowered and suggestions for the new safety stock and cycle stock levels, as well as suggestions for (2) which stock items could be totally removed from the warehouse as they have not had any consumption in many years, in the three biggest item categories: 62506 Control systems and ADP, 62703 Hydraulic cylinders and 62503 Fuses and fuse boxes.

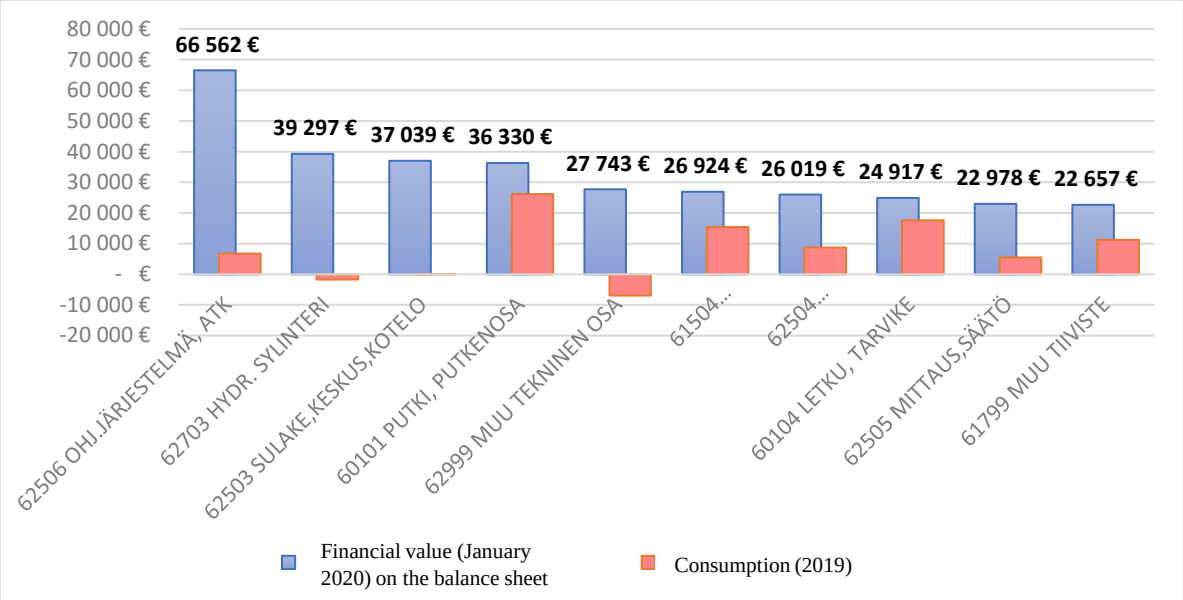

Figure 14. The 10 item categories with the biggest financial value

Inventory turnover is one of the best ways to measure the efficiency of the warehouse. In this thesis, the inventory turnover for each stock item was calculated by dividing the yearly consumption from 2019 with the average inventory. The average inventory was calculated by dividing the determined order quantity for the stock item with two and adding the order point inventory amount in it. It was not possible to get the cycle stock and safety stock levels determined for each stock item, thus simplified the order quantity represented the cycle stock and order point the safety stock. Hence, the calculated inventory turnovers are approximate but can be utilized for identifying those stock items that have relatively high inventory levels compared to their yearly consumption and those stock items that are consumed a lot from the warehouse. After calculating the inventory turnover for each stock item, the turnovers were divided in categories so that their distribution could be presented in a more illustrative way. *Table 8* shows the number of stock items in different inventory turnover categories. The table shows that there are 104 stock items, which inventory turnover is negative. This means that these stock items have been added more to the warehouse than they have been consumed. Practically this negative consumption can be a result of e.g. (1) the company adding its old, used spare parts to the warehouse, (2) spare parts that have belonged to a new machine are added to the warehouse or (3) in the yearly inventories it was noticed that the stock levels in the ERP-system are lower than they in reality are and hence the inventory balance is corrected upwards.

Table 8. The number of stock items in inventory turnover categories

Inventory turnover	Count of different stock items	Sum of Financial value on the balance sheet (January 2020)
<0	104	62 080,36 €
0	3363	296 221,98 €
0,01 – 1	768	153 109,25 €
1,01 – 2	253	51 386,08 €
2,01 – 3	105	23 863,04 €
3,01 – 4	60	17 774,38 €
4,01 – 5	25	4 201,61 €
5,01 – 6	21	1 969,38 €
6,01 – 7	8	1 377,97 €
7,01 – 8	8	1 842,72 €
8,01 – 9	3	654,21 €
9,01 – 10	6	716,52 €
>10	13	8 810,10 €
Not possible to count	5	45,12 €
Grand Total	**4742**	**624 052,72 €**

Table 8 showed that there are 3363 stock items in warehouse 4010, which inventory turnover has been zero during year 2019. When those stock items that have been used during the last four years are taken away from these 3363 stocks items with zero inventory turnover, remains 1357 stock items that have not been used in over four years and tie up 140 688€. The case company was provided a list of these 1357 stock items and suggested that these stock items could be removed from the warehouse because they tie up relatively much capital and are taking unnecessarily shelf space in the company warehouse. For those stock items, that has an inventory turnover of zero and the stock items have not been consumed in two to four years, the reorder point and order quantities could be lowered significantly, because it is highly unlikely that these are suddenly required in big quantities and therefore the demand can be satisfied with significantly smaller inventory levels.

There are 768 stock items in warehouse 4010, which inventory turnover has been between 0,01 – 1 during year 2019 *(Table 8)*. This means that either the consumption of these have been very low or the safety stock and cycle stock are relatively high. Therefore, for these stock items the order quantities and order points are lowered, so that in the future the purchases are not so big and hence, these stock items do not tie up so much of capital in the future.

Next, the stock items were analyzed from the viewpoint of how many production machines uses the stock item i.e. to how many machines the specific spare part can be used for. The case company has a lot of different machines and one spare part can be used for example in 50 different machines. Therefore, it was reasonable to analyze the stock items considering their consumption and machine connections. It can be assumed that those stock items with no machine connections and no consumption in over four years are unnecessary and moreover, those stock items with no machine connections are not critical for the production. *Table 9* demonstrates how many stock items there are in warehouse 4010 that have no machine connections and when they have last been consumed. Again, it can clearly be seen that there are a lot of unnecessary items in warehouse 4010, while there are 1293 items that have no machine connections and have not been consumed in over four years. These items tie up over 76 298€ and hence they are suggested to be removed from the warehouse while they clearly are not used anymore. In addition, those stock items that have not been consumed in two to four years are suggested to be marked in the ERP-system with a code that means the item should not be ordered anymore or is ordered only for true need.

Table 9. The relation of zero machine connections to consumption over time

Last consumption	Number of stock items with no machine connections	Sum of Financial value on the balance sheet (January 2020)
No information	531	2 067 €
Under 1 year	1025	169 476 €
1-2 years ago	212	28 613 €
2-3 years ago	122	12 124 €
3-4 years ago	176	25 862 €
4-5 years ago	1293	76 298 €
Grand Total	**3359**	**314 441 €**

When analyzing the stock item data, one item category came up many times: item category 61801 Vee belts and vee belt pulleys. This item category is amongst the ten most consumed item categories and nearly all of the items in this category are purchased from one supplier. 53 stock items in this item category are bought from this supplier and the total purchases was 11 426 € in year 2019. This supplier already has one CRP-warehouse on the mill area and therefore these stock items could be moved to that warehouse. Although this would not move the possession of these items in the warehouse to the supplier, this would however mean less administrative work by removing the need to do purchase orders. In addition, while the CRP-warehouse is already set up with this supplier, it would be easy to add these

items into the warehouse and the supplier could take care of the replenishment of these items according to already agreed on procedures.

In each step of the analysis, stock item specific information of suggested changes was added to the initial stock item data. However, during the analysis some overlapping or inconsistent suggestions for change appeared while analyzing the stock item data from different perspectives, and they were corrected during the analysis process. Also, many of the stock items come up in several lists and hence the analysis above skews the final result for example considering items that are suggested to be removed from the warehouse. Therefore, detailed information of which changes should be made for each stock item were gathered together with the help of a Pivot table in Excel. The final result of suggested changes for the case company is demonstrated in *Table 10*. This was considered important because the amount of suggested changes was big and this helped in sharing lists of stock items forward in the case company for the right departments or employees to examining.

Table 10. Suggested changes for the stock items in warehouse 4010

Suggested change	**Number of stock items**	**Sum of Financial value on the balance sheet (January 2020)**
No changes	1951	354 920,93 €
Remove from the warehouse	1045	52 525,89 €
Remove from the warehouse or lower order point and quantity	10	258,76 €
Remove from the warehouse or change to PD-code	54	9 118,24 €
Move to the already existing CRP-warehouse	27	8 691,46 €
Move to the already existing CRP-warehouse or lower order point and quantity	26	3 556,25 €
Set up a consignment stock for protective clothing and equipment	96	16 764,55 €
Set up a consignment stock for protective clothing and equipment or lower order point and quantity	19	1 719,11 €
Change to PD-code	29	1 633,09 €
Set up a consignment stock for pipes and valves	313	33 587,28 €
Set up a consignment stock for pipes and valves or lower order point and quantity	211	19 449,64 €
Lower order point and quantity	507	92 478,68 €
Lower order point and quantity or change to PD-code	17	8 803,55 €
Change to ND-code	1	- €
Change to PV-code	436	20 545,29 €
Grand Total	**4742**	**624 052,72 €**

Altogether 1045 stock items were suggested to be entirely removed from the warehouse and company ERP-system. These items are mainly those with no consumption in over four years and no machine connections, which means that these are for example electro and automatic control equipment that are not technically up-to-date or unused office supplies. Although the disposal of old items in the warehouse seems harsh because they have been paid for, it is also important to consider that keeping these items in the warehouse causes constantly costs. In addition, by removing these items, it is possible to release shelf space and make the yearly inventories easier. The case company can also try to sell some of these stock items for e.g. suppliers at low price, which would practically mean that working capital would instantly be released for more important uses.

For many of the stock items, it was suggested that the coverage group should be changed. This would not precisely release working capital but as the coverage group determined the ordering policies of the stock item, right coverage groups for stock items could prevent unnecessary purchase orders to being made. For example, if the stock item is in some CRP-warehouse or consignment stock and the coverage group is Z1, the item might be ordered in vain. Changing these to PV-coded would prevent this from happening. Also, the right coverage groups ease the work of the material resource planner.

A very concrete way to release working capital tied up in inventories, is to set up a consignment stock. It was suggested for the company that two separate consignment stocks could be set up: one for protective clothing and equipment and one for pipes and valves. A consignment stock would tie up the suppliers working capital, while the items in the warehouse are in the possession of the supplier. The case company would pay for the items only at that stage when the items are taken from the warehouse for direct use. Both for protective clothing and equipment, and for pipes and valves, the consumption has been very high during the year 2019 and the both item categories are being consumed a lot also in the future. High consumption and high inventory turnovers are usually a prerequisite of the supplier, because the consignment stock must be profitable also for the supplier. Furthermore, one benefit of consignment stocks would be that the case company would not have to make purchase orders for these items anymore. Especially for the protective clothing and equipment the amount of made purchase orders during one year are huge.

In addition, for many of the stock items, it was suggested that the reorder point and ordering quantity would be lowered. The company was provided a list of suggestions for the new

reordering points and quantities for each stock item, based on previous consumption and number of machine connections. It was not worthwhile to calculate the ordering points and quantities by using the formulas presented in the theoretical part, because not all of the required information was available and neither did the company consider it necessary. The case company could however utilize an ABC-analysis when determining the order points and quantities, as well as the desired inventory turnover. An ABC-analysis was not conducted in this thesis because it was not directly the target of this study, and it would have required spare part specific information and capabilities to understand the criticality of a specific spare part for the production.

Basically, the case company can release working capital by lowering safety stocks and cycle stocks, by setting up consignment stocks and by getting rid of those stock items that have not been used in many years and they are not needed anymore. However, it should be considered that the working capital is released as the suggested changes are realized. For example, lowering the reorder point and order quantity releases working capital in the future when subsequent purchases are made in lower order quantities than they would have been made without the changes.

4.6 Releasing working capital tied up in the CRP-warehouses

The company has five CRP-warehouses on mill area, of which four of them does not have an ERP-system code and therefore their inventory levels and purchase orders are not maintained in the company ERP-system. These four CRP-warehouses with no ERP-system code are chosen as target of this thesis. The order quantities and order points for each item in the stock are determined by the case company and the suppliers regularly follow the existing inventory levels and replenishes them if needed on behalf of the case company. The CRP-warehouses have been considered practical, while they have removed the need of making purchase orders and maintain their inventory levels in the ERP-system. However, at the moment the problem with the CRP-warehouses is that there seems to be confusion about which items actually belong to the contract, which items have been removed and which items are added to the CRP-warehouse contract after they have been used from the case company's own warehouse. In addition, while the inventory levels and actions are not maintained in the ERP-system, the exact amount of capital tied up in these warehouses and hence their

obsolescence is not possible to follow, and makes the management of these CRP-warehouses even more difficult.

In the case company these CRP-warehouses are referred as “JOT-warehouses” and hence, for clarity reasons these four CRP-warehouses are named as (1) JOT X, (2) JOT Y, (3) JOT Z and (4) JOT Q. The capital letter refers to the supplier. It is quite challenging that these warehouses are incorrectly referred as “Just-On-Time” -warehouses, while they actually are CRP-warehouses. The employees also lack knowledge of what is the actual difference between the CRP-warehouses and consignment stock. The list of warehouses with warehouse specific information which were presented earlier in chapter 4.4 could help in tackling this problem, but this is not further discussed due to its low significance to the topic of this thesis.

The purpose of this chapter is to analyze the current state of the CRP-warehouses and find out if it is possible to release working capital by making the operations more effective and lowering the order quantities of items with slow inventory turnover. The analysis of each warehouse is done on the basis of available information from the stock items and the suppliers. The basic idea is to ensure that the stock items in these warehouses have high inventory turnover because it is more cost-effective that the supplier fills in many different items in bigger lot sizes in the warehouse during its visit on the mill area.

4.6.1 CRP-warehouse: JOT X

This CRP-warehouse is located on mill area and the supplier for this warehouse is from now on referred as “Supplier X”. This is a small CRP-warehouse, consisting of only 38 different seals for specific applications. All the seals in the warehouse are owned by the case company. The inventory level follow-ups and replenishments are made once a week by Supplier X and the replenished items are invoiced once a month.

The replenishments for this warehouse have been 5 073,53€ in total during year 2019, indicating that this warehouse is quite small scale. Only 21 of the items in this warehouse were replenished during year 2019 and the total amount of replenishments were 46 pieces. The replenishment quantities are already very low, while the items are always replenished one or two pieces at a time.

Not many development suggestions for this warehouse can be proposed, while this warehouse seems to be working fine as it is. However, the Supplier X has showed interest in changing this warehouse to a consignment stock. This would be an easy way to release working capital tied up in these items, while the consignment stock would tie up the suppliers working capital. In addition, the Supplier X would probably be interested in setting up a consignment stock for these items, while the cooperation between the case company and Supplier X has been long lasting concerning the CRP-warehouse and hence the Supplier X is well aware of how much each item is consumed.

4.6.2 CRP-warehouse: JOT Y

Supplier Y is the supplier of electro and automatic control equipment and components CRP-warehouse, "JOT Y". This warehouse has been on the mill area for a long time. Supplier Y checks the inventory levels of the items once a week and replenishes the inventories if needed. The replenished items are invoiced after each visit, but the Supplier Y does not charge a service charge of each replenishment. All the items in the warehouse are owned by case company, and hence tying up working capital of the case company.

Supplier Y has invoiced the case company with 55 859,92€ concerning this CRP-warehouse during year 2019. This warehouse contains 814 different items and 254 of them have been replenished during year 2019. The total number of replenishments has been 531, of which it can be concluded that during one replenishment time many items have been replenished to the warehouse at the same time. The inventory turnovers have been relatively high in this warehouse, while on 213 items the inventory turnover has been over one during the year 2019. However, there are 560 items that have not been replenished at all during year 2019, which means that 68,8% of the items in this warehouse have not been replenished at all. This however can partly be explained by the fact that many of these items are replenished in big lot sizes and therefore their order points are not reached so often.

Firstly, a suggestion for managing the JOT Y -warehouse more effectively and hence release working capital is to update the contract of which items actually belong to the warehouse, which have been removed and which items should be added to the contract after the items have been used from the case company's own warehouse. Secondly, for those items in this warehouse which have very slow or zero inventory turnover during year 2019, the order

point and order quantities could be lowered so that the inventory levels for these items would be lower in the future and hence they would tie up less working capital when future replenishments are made.

4.6.3 CRP-warehouse: JOT Z

This CRP-warehouse is located on mill area and the supplier is named “Supplier Z”. The warehouse contains mainly seals and O-rings, and all the items in the warehouse are owned by the case company. Every item in this warehouse has its own stock item card and when the item is in short supply, the employee of the case company puts the stock item card in a predetermined place and the supplier E replenishes items based on these cards. Supplier Z fills in the items in short supply once a week and takes the new cards along for next week’s delivery. By doing this, it is possible to reduce excessive work and the upkeep of the warehouse is effective for both parties. The filled items are invoiced once a month and the supplier Z does not charge a service charge of each replenishment.

There are 370 different stock items in this warehouse. When viewing the replenishments from year 2019, it turned out that only 106 different items were replenished in this warehouse. This means that slightly under ¾ of the items were not replenished at all during one year. The replenishments for this warehouse were 2 606,30€ in total during year 2019. The number of replenished items were 98 pieces in total, which roughly estimated means that on average only two items were replenished to the warehouse weekly. Of course, the consumption of spare parts can fluctuate a lot, but the greatest benefits from CRP-warehouses are achieved by keeping items with high inventory turnover in them and therefore getting the weekly replenishment volumes up.

Firstly, a suggestion for managing the JOT Z -warehouse more effectively and hence release working capital is to update the contract of which items actually belong to the warehouse and which have been removed and after that the case company could improve its monitoring practices for the replenishment of items and total costs. Secondly, more items with high inventory turnovers should be added in this warehouse in order to benefit more from this kind of supplier collaboration. The total purchase orders made via the ERP-system for this supplier Z were approximately 52 000 € in total during year 2019, which means that there certainly are a lot of opportunities for increasing the efficiency of this warehouse by adding

more items on the contract of this warehouse. Also, in the previous chapter it was suggested that vee belts and vee belt pulleys could be moved to an already existing CRP-warehouse and the JOT Z-warehouse is the one they could be moved to. These suggestions for further development would benefit both parties, while the case company would not need to do purchase orders in vain and the supplier Z would not need to handle and confirm these orders, since the items would anyway be purchased from this supplier.

4.6.4 CRP-warehouse: JOT Q

This warehouse consists of fixings and fasteners, and the supplier for this warehouse is from now on called "Supplier Q". Supplier Q takes care of the replenishment of the stock items on behalf of the case company based on similar concept with stock item cards as in the previous JOT Z-warehouse. Also these items are invoiced once a month and the supplier Q does not charge a separate service charge of each replenishment.

This warehouse contains 765 different items. During one year the replenishments have been slightly over 46 000 € and of the 765 items, 361 have been replenished. The inventory turnovers for these items have been relatively higher than in the other CRP-warehouses. The highest inventory turnover value for an item was 40, which can be seen as a really high inventory turnover. Also 323 other items in this warehouse had an inventory turnover over one, which is relatively high for small fixings and fasteners that are purchased in big lot sizes. However, also this warehouse contained a lot of items that have not been replenished in a long time. According to supplier Q reports, there are 306 items in the warehouse that have not been replenished at all after September 2018. Although 306 items seem a lot, many of these items are replenished in big lot sizes and therefore their order points are not reached so often.

For this warehouse it is not reasonable to give development suggestion because in general everything seems to be working just fine. The replenishments and the inventory turnovers are already relatively high in this warehouse, which means that many benefits have been achieved with using the continuous replenishment policy for the fixings and fasteners. Supplier Q replenishes the warehouse in big volumes and therefore the case company has does not need to make many purchase orders. In addition, while the inventory turnovers are

relatively high, the items are not staying on the shelves for long times and hence not tying up working capital for long times.

4.7 Development suggestions for inventory management in the future

The previous chapters provided suggestions on how to release working capital tied up in the specific warehouses. The means of inventory management for releasing working capital in the case company were mainly removing unnecessary items from the warehouse, lowering the order points and quantities, setting up consignment stocks and clarifying procedures of action. The analysis of the CRP-warehouses revealed that in some of the warehouses the inventory turnovers are low and therefore the weekly replenishment quantities are low. This problem could be solved with the development suggestions found in chapter 4.6, while based on this chapter many of the items could be moved to a CRP-warehouse or consignment stock. Hence, by transferring items with high inventory turnovers to CRP-warehouses or consignment stock, the biggest benefits can be achieved of these warehouses and it is possible to decrease order placing. This chapter proposes development suggestions for the company's inventory management in the future, enabling the company to manage its inventories more efficiently in the future and hence reduce the amount of working capital tied up in inventories. Inventory management in the case company seems to be in need of improvement and common operating rules for effective inventory management are lacking or they are not being followed by the employees.

At the moment, inventories tie up huge amounts of capital and in general the inventories seem to be quite old due to low or no consumption of many stock items. It should be noted that the inventories mentioned in this thesis are only consumables that are mainly for the use of maintenance, meaning that they are not direct purchases for the final product such as raw materials are. However, these are necessary items for the continuity of the production and make revenue generation possible, and hence the company must maintain relatively big inventories of spare parts in order for all necessary spare parts being available immediately when needed. In addition, while many machines use the same spare parts, the case company have decided that there always must be more than one of each different spare part available. Nevertheless, this way of thinking has expanded out of control in the case company while large quantities of spare parts are being kept in the warehouse with the idea that all machines

would break at the same time and then these spare parts would be needed in large quantities. The risk for all machines needing a specific spare part just at the same time is extremely minor. Next some suggestions for tackling these issues are presented.

Firstly, the case company could greatly benefit from an ABC-analysis or corresponding item classification model. The company has a huge amount of different stock items and while a huge part of the items in the warehouses are spare parts for the production machines, a comprehensive criticality analysis would help in managing the inventories as item classes and hence reduce the time spent on inventory control. The service level in the A-classified spare parts should be maintained high, while the service level of the item in the insignificant C-classified items could be lower and hence reduce the amount of tied up capital in inventories and save in the overall cost of holding inventories. The case company could also utilize the ABC-analysis in determining optimal order points and order quantities for the already existing stock items.

Secondly, the instructions for creating new stock items should be clearer. At the moment, all new stock items should be accepted on higher level in the organization, but this rule is not always followed. Unnecessary stock items and incorrect item information raises the amount of stock items in the company ERP-system and makes the management of them more difficult. The company should also consider a clearer instruction on how new stock items should be named in the ERP-system. The instructions should clearly state which information should be included in the name (e.g. item name, size and material) and which information should not be included (e.g. supplier names). The instruction should also assist the employees on how to determine the right order points and order quantities for the stock item, because currently the determination of these are based on the opinions and capabilities of the employees. The order points and order quantities however straightly influence the amount of tied up working capital and hence they might have a huge influence on the tied up working capital in the long run.

Thirdly, the company should improve the cooperation between different departments. The objective of this thesis was to get a comprehensive data of the stock items and connect reports utilized by different departments in the case company. By doing this, it revealed that the finance department makes reports of inventory obsolescence and ageing for each stock item, but they are never utilized for any other purposes than for accounting. These reports could easily be shared for the mill services, where these reports could concretely be utilized for

better inventory management, following the turnover of the stock items and making sure that items that are vulnerable to be perished over time could be inspected regularly.

Finally, the company could benefit from doing a similar, comprehensive analysis for each of its warehouses and optimize the inventory levels in them. Also, the follow-up of the current situation of inventories could be improved and made regularly and hence, actions for reducing the capital tied up in inventories could be taken ahead of time.

5 DISCUSSION AND CONCLUSIONS

Inventory management has two principal goals. Firstly, ensuring that there are enough inventories to maintain operations and secondly, reduce the ordering and upholding costs of the inventories to the minimum. Inventory management should determine the right ordering quantities when considering future demand by simultaneously avoiding overstocking and understocking, try to avoid losses caused by spoilage and inventory obsolescence, and furthermore minimize total inventory costs and increase efficiency. The annual total inventory costs can be up to 20 – 36 % proportionated to the total inventory value and hence it is clear that the inventory levels are, the more cost they cause. Inventory management does not only strive for decreasing the amount of capital tied up in inventories, but also comprehensively taking into account logistic costs and total costs of inventory, and whilst considering the service level requirements for the inventory. By optimizing only one parameter e.g. lowest possible inventory levels, it is not possible to achieve the best result relative to total costs and profitability of the company.

This master's thesis examined the means of inventory management as a way to release tied up working capital. The main objective of this thesis was to understand how effective inventory management affect the tied up working capital and which are the inventory management policies that should be favoured when trying to reduce the capital tied up in inventories. The next chapters provide the answers for the research questions and the final conclusions how working capital can be released in the case company by the means of inventory management.

5.1 Answering the research questions

In this chapter the research questions are answered based on reviewed literature in the theory part and the empirical part of the thesis. First the three sub-questions are answered:

Sub-question 1: "How does inventories affect working capital?"

Working capital consists of a company's current assets and current liabilities. It is the investments a company makes in its short-term assets, including cash, accounts receivables,

accounts payable and inventory. Inventories are a part of a company's current assets and therefore a part of working capital. The more the company has inventories, the more the company needs working capital and therefore one primary objective of inventory management is to maintain inventories at a level where the set goals of the company can be achieved. However, the meaning of inventory management is not to minimize or remove all the inventories, but rather optimize them so that capital is not tied up in excessive inventories but the company has enough inventories to meet the demand of customers or the requirements of the production. Basically, all of the inventories standing in a company's warehouse, excluding accounts payables, tie up working capital and constantly cause holding costs, and therefore the inventory should be transferred into cash as soon as possible.

Sub-question 2: "What are the means of inventory management?"

Inventory management should determine the right ordering quantities when considering future demand by simultaneously avoiding overstocking and understocking, try to avoid losses caused by spoilage and inventory obsolescence, and furthermore minimize total inventory costs and increasing efficiency. Therefore, the means of inventory management are calculating the appropriate cycle stocks, safety stocks, reorder points and replenishment quantities for the company in question and the nature of demand by using e.g. deterministic models (EOQ or EOI) or probabilistic models (safety stocks, service level and probability distributions).

Different inventory classification models are important tools in inventory management, especially in spare parts inventory management where it is useful to categorize spare parts according to their criticality. Item classification is used for improving the administrative efficiency of all types of inventories. The most well-known and the most widely used classification method is the ABC-analysis. Inventory classification models are useful especially when the company has thousands of items in its warehouse and by classifying the items according to their importance for the company, it is possible to apply different ordering and management policies for each category. This helps in directing most attention and time in controlling the A-classified items while their value is so significant proportion of the total inventory value.

Measuring the performance of inventories with different ratios is an important mean of inventory management. The most commonly uses inventory ratio is the inventory turnover ratio which measures how efficiently the company has used and replaced its inventory during a given period. The ratio indicates that the higher the inventory turnover is, the less capital is tied up in inventories because the inventories are efficiently being used from the warehouse.

Sub-question 3: "What is the role of supply chain collaboration in releasing working capital?"

The importance of supply chain collaboration as a part of the strategic planning in companies and as a way to create competitive advantage has increased continuously. Closer relationships with suppliers are acknowledged as an opportunity to achieve cost reductions and increase revenues as well as a tool to increase flexibility in dealing with supply and demand uncertainties. The just-in-time philosophy has proven to reduce inventories in the supply chain, while the purchases are made in smaller lot-sizes and due to reduced lead times, the companies can maintain lower inventories.

Collaborative techniques such as vendor managed inventories (VMI), continuous replenishment program (CRP) and consignment stocks, where the management of inventories outsourced either completely or partially, have proven to reduce administrative work and costs. Especially large companies have achieved significant improvements in inventory performance and working capital management with vendor managed inventories. By setting up a consignment stock, savings from 20% up to 40% of the annual management costs can be achieved when compared to the traditional EOQ policy. Especially consignment stocks are useful in releasing working capital because the items in the consignment stock tie up the suppliers working capital. However, equally the supplier benefits from a consignment stock arrangement while it does not have to bear the stocking costs.

Based on the findings on the sub-questions, a final answer for the main research question can be formed:

The main research question: "How can working capital be released by the means of inventory management?"

As a conclusion, it is possible to decrease the amount of capital tied up in inventories by holding the inventory levels low and keeping the inventory turnover ratio high. Moreover, working capital can be released by removing unmarketable products from inventory, dividing products into purchasing categories, using vendor managed inventory systems and creating rules for re-purchase times for each product category. The fundamental logic of stocking and replenishment decisions must be finessed to follow the demand. By doing this the company is able to produce and sell more with a lower inventory balance, while simultaneously improving margins due to obsolescence write-offs, order expediting and reduced overtime. Finally, in many cases it is not reasonable to store all items by the company but rather ensure fast and reliable availability from suppliers. Especially expensive stock items that have short delivery times, should be considered to order only when needed rather than keeping them in stock waiting to be used.

5.2 Conclusions

The case company for this thesis is a manufacturing company and they usually have the most difficult and complex inventory problems, while they purchase raw materials and change their form to create value as finished goods. Hence, they have a lot of capital tied up in inventories and the importance of effective inventory management is emphasized. This thesis focused on consumables inventories and although they are not directly used for producing the final product but they are rather enabling the continuity of the production, it is equally important to manage them effectively. Actually, in the case of consumables and spare parts it may be even more important because these items can have extremely minor and fluctuating demand, but due to their importance and criticality for the production, they must be held in inventories even for long time periods and thereby they tie up working capital for a long time. However, this study revealed that the case company has relatively much excessive working capital tied up in inventories and the inventory turnover is relatively slow on average, which means that there certainly is a great potential to release working capital by making the management of inventories more effective. By doing so, capital is released for more important uses in the case company.

As a first conclusion, the case company could greatly benefit from and require an multicriteria ABC-analysis or a similar approach to spare parts management as the model of Huiskonen (2001, 132) presented earlier in chapter 3.3.3, in order to assess the criticality of the spare parts and components in the warehouse. The company has altogether tens of thousands stock items in its warehouse and therefore it is not reasonable to manage all of them in the same way. The item classification helps in directing more managerial attention to the most important and critical items for the company and moreover, simplifying operating modes for those items that are not so valuable for the company and can be managed in more straightforward ways. Thus, the item classification helps in determining the right reordering points and ordering quantities for the stock items and thereby making sure that working capital is not tied up in excessive and non-important inventories.

Moreover, the case company has several more ways to release working capital. Firstly, unnecessary stock items that have not been used in many years and are not critical spare parts should be removed from the company's own warehouse while they constantly cause costs. Rather the company should ensure fast and reliable availability from suppliers for these items in case the items are needed later. Secondly, for the many stock items with slow inventory turnovers, the reorder points and order quantities should be lowered in the company ERP-system so that the inventory levels of these items would be lower in the future and the inventory turnover ratio could be increased. Basically, this means that the safety stocks and cycle stocks for these stock items would be lower in the future. Thirdly, setting up consignment stocks for items with rather high consumption was suggested as a way to release working capital. This would tie up the suppliers working capital and in addition it would reduce the administrative and managerial costs, but equally the supplier would benefit from the consignment in reduces inventory holding costs. Fourthly, the study revealed that the company does not utilize its CRP-warehouse to their full potential. At the moment in many of the CRP-warehouses the inventory turnovers are very slow and they include relatively much items that have not been replenished at all during the last year. This problem can be solved by lowering the reorder points and replenishment quantities of these items and by moving some of those items with the highest inventory turnovers purchased from the specific supplier to the already set up CRP-warehouse of that supplier. Hence, biggest benefits can be achieved from these VMI arrangements and it is possible to decrease order placing and administrative costs.

Finally, it should be considered that working capital is released as the suggested changes are realized. For example, lowering the reorder point and order quantity releases working capital in the future when subsequent purchases are made in lower order quantities than they would have been made without the changes. In the future the case company should focus on clarifying and standardizing operating modes in its inventory management and emphasize cooperation between the departments so that their divergent goals of inventory management can be harmonized in the best way while considering the business and its objectives and hence a consistent strategy for the management of inventories can be formulated.

5.3 Validity, reliability and limitations

This thesis was conducted for a case company and therefore the data used in this thesis is only from that one company, which directly limits the usability of the results of the study in a wider context. However, the means of inventory management and how they can be utilized in releasing working capital are in theory the same for every company, they just have to be justified to align the nature of demand and the goals of the company.

This study focused exclusively on studying the effects of consumables on the tied up working capital, which for its part sets limitations for the applicability of these findings for other types of inventories e.g. raw materials or finished goods. Moreover, the case company is a manufacturing company and therefore the results of this thesis may not be applicable for example in distribution companies.

Reliability of the results refers to the consistency of the analysis and the reproducibility of the results. While this was a case study where the analysis of the inventories were made based on the data from year 2019, and the financial values and inventory levels were the values from the end of January 2020, the results might not be entirely the same if the analysis was made with the corresponding values from another time. This due to the fact that demand and consumption varies a lot over time and an item may just have been replenished and therefore its inventory levels can be higher than on average. However, this problem was acknowledged by taking the inventory obsolescence into consideration, which gave information of when the item has latest been consumed from the warehouse. Moreover, the validity of the study may have been affected by the limitations in the available data, whilst the reports from the ERP-system may have had some limitations and all inventory

transactions might not have been entered in the ERP-system or they may have been incorrectly.

Finally, it should be noted that the findings in this thesis are presented as development suggestions for the case company and it may be that all of the suggestions are not applied in practice. All the lists of stock items provided for the company must be gone through case-specific by someone who understands the criticality of the items for the production and thereby no crucial items are removed from the warehouse or their inventory levels are lowered too much.

5.4 Future research

The theories presented in this thesis are widely studied and there are no remarkable research gaps. However, suitable inventory policies for spare parts are less studied and due to their complicated special characteristics, it would be interesting to study the categorization and suitable policies for each category more widely. The earlier presented model of Huiskonen (2001, 132) for spare parts categorization and respective policies, could be further studied and its applicability for the future could be more widely tested for different industries. Moreover, while the traditional inventory policies such as EOQ and EOI are rarely suitable for spare parts, the future research should focus on studying how for example appropriate inventory levels can be determined for spare parts.

Similarly, the future studies in the case company could focus on studying suitable inventory policies for its different spare parts and how they could be classified in the best way for the requirements of the company. All in all, the company could in the future focus on studying more effective ways to manage its working capital and studying suitable ways to effectively manage the big wholeness of different types of inventories, while it is not possible to manage all of the items in the warehouses in a similar way.

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APPENDICES

Appendix 1. List of the warehouses

Normal warehouses managed by the case company			
ERP-system code	**Type of inventory**	**Location**	**Possession**
4001	Spare parts (technical parts, valves, gaskets, couplings, pumps)	Mill area	Company owned
4003	Big spare parts (pumps, gears, fans, motors, shafts)	Rented warehouse outside of the mill area	Company owned
4006	Electro and automatic control equipment and components (control systems, ADP accessories, measuring elements, transformers)	Mill area	Company owned
4010	Small maintenance items, items for property maintenance, protective clothing and equipment, pipes and pipe links, bearings, cables, office supplies etc.	Mill area	Company owned
4011	Motors and their parts	Mill area	Company owned
4012	Flammable liquids (detergents, inhibitors, lubricating oils)	Mill area	Company owned
4016	Industrial oils, radiator fluids	Mill area	Company owned
4019	Bars and steel pipes	Mill area	Company owned
40S1	Very small inventory of technical parts	Mill area	Company owned
40S2	Very small inventory of spare parts	Mill area	Company owned
40S5	Very small inventory of electrical components	Mill area	Company owned
4880	Tools (screwdrivers, files, hammers, pliers, adjustable wrenches)	Mill area	Company owned
Warehouses with supplier collaboration			
ERP-system code	**Type of inventory**	**Location**	**Possession**
4007	Spare parts that are stored in supplier warehouse. Warehousing contract.	Supplier premises	Company owned
4008	Warehouse with just-in-time characteristics, the supplier has promised that these spare parts are always delivered within a few days	Supplier premises	Supplier owned
4009	Continuous replenishment policy (Basically the same as CRP-warehouse “JOT Y”)	Mill area	Company owned
4013	Spare parts that are stored in supplier warehouse. Warehousing contract.	Supplier premises	Company owned
4014	Warehouse with just-in-time characteristics, the supplier has promised that these spare parts are always delivered within a few days	Supplier premises	Supplier owned
4015	Vendor managed inventory	Supplier premises	Company owned
4100	Continuous replenishment policy	Mill area	Company owned

4900	Warehouse with just-in-time characteristics, the supplier has promised that these spare parts are always delivered within a few days	Supplier premises	Supplier owned
4901	Warehouse with just-in-time characteristics, the supplier has promised that these spare parts are always delivered within a few days	Supplier premises	Supplier owned
4903	Spare parts that are stored in supplier warehouse. Warehousing contract.	Supplier premises	Company owned
4904	Spare parts that are stored in supplier warehouse. Warehousing contract.	Supplier premises	Company owned
CRP & consignment stocks			
Inventory name (no ERP-system code)	**Type of inventory**	**Location**	**Possession**
JOT X	Continuous replenishment policy (CRP)	Mill area	Company owned
JOT Y	Continuous replenishment policy (CRP)	Mill area	Company owned
JOT Z	Continuous replenishment policy (CRP)	Mill area	Company owned
JOT Q	Continuous replenishment policy (CRP)	Mill area	Company owned
KAU	Consignment stock	Mill area	Supplier owned

Appendix 2. Size of the warehouses

ERP-system code	Count of different stock items	Sum of financial value
4001	6669	1 415 673,71 €
4010	4742	624 052,72 €
4006	4637	798 782,79 €
4003	2096	2 141 365,18 €
4011	1105	410 801,95 €
40S2	974	93 286,32 €
4009	584	- €
4015	326	225 393,91 €
4880	271	14 185,83 €
4901	185	19 000,00 €
4019	148	30 451,70 €
4014	57	- €
4900	48	- €
4008	42	- €
4016	35	58 513,16 €
40S5	15	2 418,03 €
40S1	14	1 773,47 €
4100	13	656,25 €
4012	5	7 501,71 €
4013	5	- €
4903	3	36 660,00 €
4904	1	85 000,00 €
All together	**21975**	**5 965 516,73 €**

Appendix 3. Item categories with the biggest consumption in 2019

ITEM CATEGORY	Financial value (January 2020)	Sum of Consumption (2019)
60802 SUOJAIN	10 408 €	49 216 €
60801 SUOJA-ASU, KÄSINE	8 190 €	47 638 €
61506 LÄPPÄVENTTIILI	15 693 €	28 367 €
60101 PUTKI, PUTKENOSA	36 330 €	26 223 €
60505 RASVA	17 259 €	25 954 €
60508 PIENKEMIKAALI, LIUOTIN	8 597 €	22 797 €
60104 LETKU, TARVIKE	24 917 €	17 604 €
61504 PALLO, SEGMENTTIVENT.	26 924 €	15 417 €
61799 MUU TIIVISTE	22 657 €	11 279 €
61801 KIILAHIHNA, -PYÖRÄ	21 181 €	10 342 €
Grand Total	**192 156,79 €**	**254 835,60 €**

Appendix 4. Purchases for supplier X by item category

ITEM CATEGORY	Sum of Purchases (2019)
60101 PUTKI, PUTKENOSA	19 052,31 €
61504 PALLO, SEGMENTTIVENT.	7 543,27 €
61599 MUU VENTTIILI	4 054,66 €
62505 MITTAUS, SÄÄTÖ	3 266,53 €
62223 SUIHKU, PILLI, SUUTIN	2 732,29 €
60104 LETKU, TARVIKE	1 412,69 €
69099 MUU KUNNOSSAPITO	833,39 €
61799 MUU TIIVISTE	97,68 €
63201 RAKENNUS LVI-TARVIKE	95,13 €
62220 PÄÄLLYSTYSKONE	79,65 €
Grand Total	**39 167,60 €**

Appendix 5. Item categories with the biggest financial value on the balance sheet

ITEM CATEGORY	Sum of Financial value (Janurary2020)	Sum of Consumption (2019)
62506 OHJ.JÄRJESTELMÄ, ATK	66 562 €	6 799 €
62703 HYDR. SYLINTERI	39 297 €	- 1 695 €
62503 SULAKE, KESKUS, KOTELO	37 039 €	62 €
60101 PUTKI, PUTKENOSA	36 330 €	26 223 €
62999 MUU TEKNINEN OSA	27 743 €	- 6 969 €
61504 PALLO, SEGMENTTIVENTT	26 924 €	15 417 €
62504 MUUNT., MUUNNIN, VAHVI	26 019 €	8 766 €
60104 LETKU, TARVIKE	24 917 €	17 604 €
62505 MITTAUS, SÄÄTÖ	22 978 €	5 501 €
61799 MUU TIIVISTE	22 657 €	11 279 €
Grand Total	**330 467,61 €**	**82 985,46 €**