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Developing Global Inventory Management for Spare Parts by Creating New Operational Model

Master's Thesis

Examiner: Associate Professor Petri Niemi, D. Sc. (Tech)

Supervisor: Tiina Haapalainen

ABSTRACT

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The purpose of the study was to solve common inventory management related problem in a global company. The case company's capital turnover has been partly weakening because of global inventory network includes some overlapping and non-moving inventories. The objective of the study was to research a current situation of global inventory management in the case company and create solution to the research problem. The study was carried out by following action oriented research and case study approach by using both quantitative and qualitative methods in analysis. In the empirical phase the major causes of the problem were identified by doing current state analysis, which included interviews, observes and inventory data analyses.

In the current state analysis found out that previously used inventory management policies did not provide an efficient material flow in the global inventory network. Furthermore, there was not exist performance management for inventory management. As a result of the study was created multi-criteria classification model which makes possible to control items more efficiently. In addition, there was created new parts return policy for slow-moving and non-moving inventories. In order to develop performance of the inventory management, there was created a new operational model for global materials management including target-setting and follow-up model, and key performance indicators for global spare parts inventory management.

TIIVISTELMÄ

Tekijä: Tuomas Yli-Marttila

Työn nimi: Globaalin varaosavarastonhallinnan kehittäminen uuden toimintamallin avulla

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Hakusanat: varaosavarastojen hallinta, monitasoinen varastointijärjestelmä, suorituskykymittarit

Tutkimuksen tarkoituksena oli ratkaista varastonhallinnan tyypillinen ongelma maailmanlaajuisesti toimivassa yrityksessä. Tutkimuksen kohteena olleen yrityksen pääomien kierto on heikentynyt osaltaan johtuen globaalien varastojen kasaantuneista ja kiertämättömistä varastoista. Tutkimuksen tavoite oli tutkia case-yrityksen varaosavarastojen hallinnan nykytila ja kehittää ratkaisu ongelman korjaamiseksi. Tutkimusmenetelmänä käytettiin toiminta-analyyttista tapaustutkimusta käyttäen sekä kvantitatiivisia että kvalitatiivisia menetelmiä tiedon käsittelyssä. Työn empiirisessä osuudessa selvitettiin pääsyyt ongelman syntymiselle tekemällä nykytila-analyysi, joka sisälsi haastatteluja, havainnointia yrityksessä sekä varastodatan analysointia.

Nykytila-analyysissa selvisi, että aikaisemmin käytössä olleet varastonhallinnan toimintapolitiikat eivät tarjonneet riittävän tehokasta materiaalivirran hallintaa globaalissa varaosaverkostossa. Lisäksi varastonhallinnan suorituskykyä ei mitattu eikä johdettu tehokkaasti. Työn tuloksena luotiin monikriteerinen nimikeluokittelumalli, joka mahdollistaa nimikkeiden tehokkaamman ohjauksen. Lisäksi luotiin uusi palautuspolitiikka kiertämättömille ja hitaasti kiertäville nimikkeille. Suorituskyvyn hallinnan kehittämiseksi luotiin uusi materiaalinhallintamalli, joka sisältää tavoiteasetantamallin sekä seurantakäytänteet suorituskyvyn johtamiseen. Oleellisena osana tätä kehitettiin myös suorituskykymittaristo varastonhallinnan kehittämiseksi.

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Nothing great can happen without the background support. I would like to thank my family and girlfriend who have been supporting and encouraging me during my studies. I believe that hard work and the right attitude will carry life far.

Tottijärvi, 18th May 2017

Tuomas Yli-Marttila

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ABBREVIATIONS

ABC analysis	Item classification method based on Pareto principle
CMI	Centrally Managed Inventory system
COGS	Cost of goods sold
DC	Distribution center
EOQ	Economic Order Quantity
ERP system	Enterprise Resource Planning system
KPI	Key performance indicator
OTD	On Time Delivery
ROP	Re-Order Point
SKU	Stock Keeping Unit
TIDS	Total Inventory Days of Supply

1 INTRODUCTION

1.1 Background of the study

At the same time when companies have begun to focus on efficient working capital management, their existing customers are beginning to insist better availability and service level for spare parts. A good availability of spare parts is one of the main features what customers are expecting. In spare part business, customer satisfaction and service level are closely connected with each other. Customers' machine break down situations can be extremely costly to the customers if they are waiting for spare part a long time. A good service level ensures customers' desiring for cooperation for future too. On the other hand, companies have started to optimize their current assets as spare part inventories for releasing invested capital to other functions.

Inventories are a natural part of the business, and there is very common belief that to do business with low inventory levels is not possible. Due to the spare part uncertainty of demand and lead times, keeping inventories is necessary. However, this does not change the fact that it is still reasonable to aim for efficient and optimized inventory and materials management in the supply chain because large inventories tie significant amounts of company's capital. One reason for avoiding too big inventories is that inventories tend to hide existing problems; they make it easier to live with problems rather than eliminate them. However, inventories are costly to maintain. In addition, customers do not care how many parts are stocked because it does not increase the added value. Customers expect good service level, the availability of parts, not large inventories. Sufficient service level is possible to achieve with lower inventory levels when cooperation and information transparency are improved in the whole supply chain. Large inventories in the supply chain are usually a sign of problems and lack of trust between organizations or functions. Also, successful inventory management is often the mark of a well-run organization. (Sakki 1999, pp. 90-91; Stevenson 2007, p. 577)

In spare part business, inventory level and service level have to be closely examined. A well-managed spare part business calls for a balance of the scale where are inventory levels and invested capital in inventories, and service level and customer satisfaction. Often people think that it is not possible to find balance in the scale by optimizing the spare part inventory management and it is always seen as a trade-off. Inventory management optimization is especially relevant in inventory models like the case company group's global supply chain where spare parts are stocked worldwide. Especially in this kind of situation, it is necessary to pay close attention to develop inventory management policies, to keep service level high and invested capital in inventories at the low level. The larger service network company has, the better materials management is required.

Recently, customers are more informed about spare parts sources and supplier channels. In addition, customers can find a replacement from other distributors. E-commerce has made it possible to find the equivalent spare part and usually with a lower price. Globalization has been providing new ways for customers and at the same time caused challenges for OEM manufacturers. Also, the piracy of spare parts has been increasingly growing which has been problematic for OEM manufacturers because of spare parts quality, and it caused other problems.

1.2 The case company and business area

The case company is a group, which includes the parent company, as well as twelve wholly-owned subsidiaries globally. The main field of business of the company and the group is the design, manufacture, sale and service cut-to-length (CTL) method forest machines, other metal products, machine control systems, vehicle PC equipment, different types of separate systems and software. The case company's net sales was over 500 million in 2016. The sales and service network covers 40 countries worldwide, and the share of exports is 77 percent of net sales. Service business generates 20 percent of company's net sales, and it has been growing continuously.

1.3 Research problem and objectives

The main goal of this thesis is to create, develop and streamline the case company's global spare part materials management processes and unify operational policies to strengthen the aftersales business. In the big picture, one of the main objectives of this thesis is to be able to create an integrated materials management to optimize the invested capital in global spare parts inventories while keeping high service level and customer satisfaction. The thesis also aims to standardize inventory management policies between the parent company of the group and subsidiaries and thus get transparency and cooperation between functions. Thus, the research problem of this thesis can be phrased as:

- There is not an integrated and a process-based materials management for the case company's global spare parts inventory network and the network carries some overlapping and non-moving inventories.

Based on research problem has created the research question of the thesis:

- How could global spare part inventory management of the case company group be streamlined and unified and avoid overlapping and slow-moving inventories?

In order to solve the research problem, the following sub-questions must be examined:

- Where should the items be stocked and how should stocking level be determined, that means, which items should be stocked locally on areas and which centrally in the distribution center?
- What part of the current spare parts supply chain processes has to be improved, streamlined and unified?
- How should inventories be analyzed, classified and controlled in future in order to manage more cost-effective and profitable inventories?
- What a kind of materials management should be created that it will be easy to implement and it will be workable in the case company's business environment?
- How should the performance of inventory management be measured and led in future?

1.4 Scope of study

The scope of this thesis focuses on a common current assets management problem which caused by oversized inventories in the case company. The scope consists of global service network spare part inventories, such as distribution center and subsidiaries' spare parts inventory management and planning, thus other parts of current assets such as new production and second-hand machine inventories are excluded from this thesis. Likewise, the supplier basis and their effect to spare parts inventory management are excluded from this thesis. The main reason for these restrictions was because these issues were not seen as a preliminary source of the problem. In addition, under the research is taken two geographically and business point of view different subsidiaries from inside the Group. This thesis work scope of research is illustrated in Figure 1.

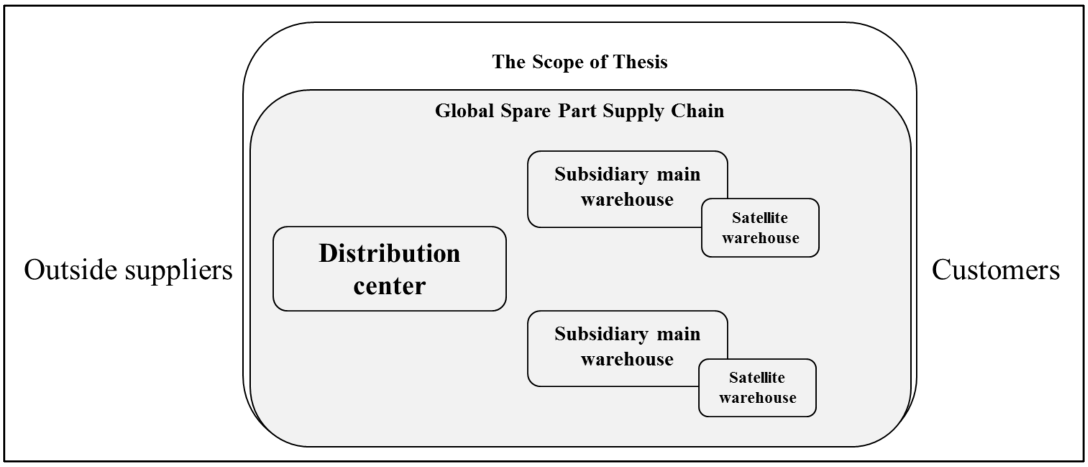

Figure 1 The scope of this thesis

1.5 Research approach and methodology

The thesis project was a part of a larger strategic project of the case company on the field of the supply chain. This thesis work focuses more on the global inventory management than the logistics issues, but it is important to understand logistics processes because their impact to inventories is remarkable.

This thesis is action oriented case study, and its purpose is to improve the specific problem and create solution for it. According to Olkkonen (1994, pp. 74-75), using action-oriented research approach the aim is to understand the problem by using and combining historical data, relevant theory and practice (see Figure 2). The action-oriented research approach is commonly used in studies of organization’s operations, management, problem solving and decision making processes. In action-oriented research approach, it is very typical that there are not external observations that could be used in the study. Although many industrial management problems are common, there are also different aspects of organizations and business areas. Thus, the researcher must understand the processes from inside the issue in order to he or she can resolve the research problem. This is because the impacts can be varied and even unpredictable. The perceptions of issue is typically got by interaction and observation. Often the results achieved by action-oriented research approach cannot be generalized because there are many specific aspects that are related to the case environment. Due to this reason results must be critically evaluated before using them in other case or wider research subject.

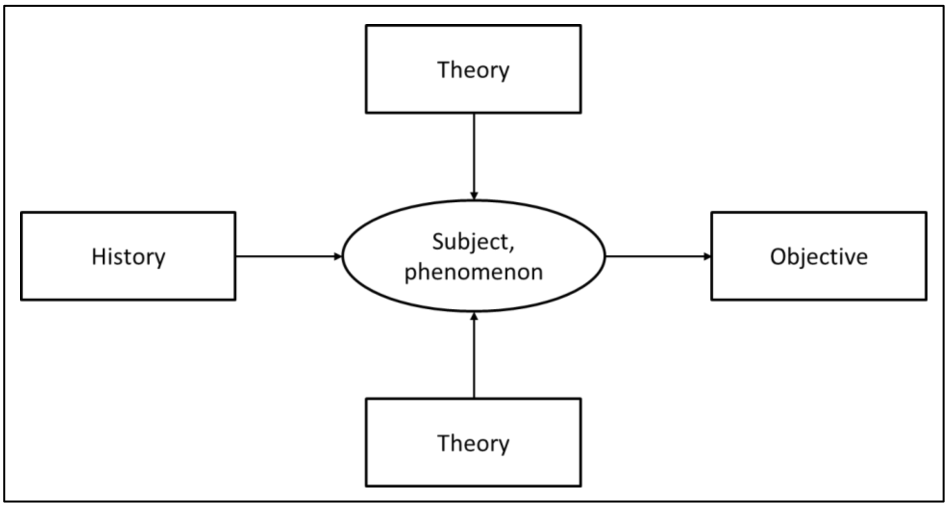

Figure 2 The perception of action-oriented research approach (*Olkkonen 1994, p. 75*)

As mentioned this study has also characteristics of a case study. Hirsijärvi et al. (2007, pp. 130-131) describe that a case study includes detailed and intensive information about one specific case or a couple of connected cases. In the case study, the subject is commonly individual, and it focuses on the specific case. The subject and its environment understanding are in a major role, and for this reason, one of the objectives is to describe phenomenon for the problem using variable research methods to collect information, such as observation, interaction and interviews, historical data analyzing and document research.

To achieve the objectives and targets of the thesis work, theoretical research will be widely discussed in this thesis. After good knowledge of the theoretical background, in this thesis will explore the current situation and describe it as widely as possible. To find a solution to the research question and the case company's current challenges, there will be interviewing people widely by crossing the organizations worldwide. Thus, an observation and exploring will be done in the subsidiaries and the parent company. In the thesis work, the inventory data analyses will also be done. In addition, the aim behind the development of solutions is to see implementation to the company's operations. Therefore, the results will be developed with a view from concept to realization. In part, the challenge is seen as the confidentiality of the thesis, so some parts of the work have to be encrypted. By using these methods aim to find solutions to solve the current problems and give to the company new development proposals as well as recommendations for further studies.

The structure of the thesis is divided into two parts. The first part of the thesis includes theoretical chapters, which deal with academic literature, such as scientific journal, research papers, and observations of these form the framework for the empirical phase of the study. In this part will be studied widely academic literature in order to provide new ideas for empirical phase and described the phenomenon behind the subject, but also introduced basic theory of spare parts inventory management. The purpose of introducing a basic theory of the inventory management is also to increase the knowledge of inventory management and provide added information of the subject in the case company.

The second part of the thesis is an empirical part. In this part of the thesis will be investigating a contemporary phenomenon within the case company context. In the empirical part, one of the main data sources were interviews. Olkkonen (1994, p. 105) notes that interviews provide qualitative data which is usually less objective than quantitative data. The reason for note is that interviews produce data, which consists of personal opinions. However, interviews are on the major role when are describing the current state of the organization and studied subject. Also, Hirsjärvi et al. (2007, p. 201) point out that interviews might distort of research data. It is, therefore, important to prepare interviews well in advance and be aware of possible causes of the errors in interviewing situation. (Saunders et al. 2009, p. 321)

The empirical part of thesis also includes data analyses based on statistical data and reports which are collected from the enterprise resource planning system. In data collection, there are many factors which can cause an error to statistics. Olkkonen (1994, pp. 104-105) notes that it is very important to understand that the data is usually based on approximation and it is not always truth. The reason for this can be caused by differences in concept definitions. It is always necessary to try to find out the source of errors and their impact on the reliability of the results. He states that errors generated during data collection and reasons are diverse. The reasons may include unclear instructions, misunderstandings, defective statistics, errors of assessment or any other unintentional or even deliberate action. However, one of the important factors can be the delay of statistics and their obsolescence. In this study, there are used approximation statistics because data is constantly changing.

In this study were used various research methods. Methods of data collections and analyzing can be divided into two main categories, which are quantitative and qualitative methods. The difference between the methods can be simplified as follows. Quantitative methods are using numerical data that can be gathered by using data collection techniques or analyzing procedures and processes which generate numerical data. Data for analyzing in quantitative method can be collected for instance from enterprise resources planning system or material planning system. Qualitative methods are information and data collection techniques which use non-numerical data. For example interviewing is qualitative research method. (Saunders et al. 2009, pp. 151-152)

In this study were combined quantitative and qualitative methods. The data of empirical phase was collected by using interviews, process exploring and data analyzing. There are done internal and external benchmarking also. In the internal benchmark is tried to find best practices and observations from inside the company. External benchmarking was done as well. There objective was to get a deeper knowledge of the challenge and get some good ideas and practices from the other similar companies. The external benchmarking is out of the thesis report scope, but the best practices and problem-solving ideas will be taken into account when solving the research problem.

1.6 Structure of the study

The previous section stated that the study consists the theoretical and the empirical part. In this section is described the structure of the study. The study has been divided into five sections including introduction, theoretical part, empirical part, results, and conclusions. Thus, the structure of the study is presented in Input-Process-Output (IPO) table. The idea of the IPO is to describe input data for process, then, output describes what process produces. (Slack et al. 2015, pp. 10-11)

In this case IPO is used to describe what input data each chapter needs and how this data is enlarged in the chapter. Hence, there is created output data, which describe what data or information chapter creates as input data for following chapters. The structure of the study with input-output data is described in Figure 3 below.

Input The purpose of the study and background information.	**Chapter 1: Introduction** Describing the development paths that led to the thesis project in the case company. Describing the case company and its business area. Defining the research problem and create a research question based on it. Defining limitations and scope of the thesis. Choosing a research methods and approach for the study. Describing the structure of study.	**Output** Understand the motives and need for the study. The case company and its business area. Research problem and research question and objectives for the thesis. Limitations and the scope of study. Research methods and approach for the study. The structure of study.
Input Academic literature of the inventory management and global spare parts management.	**Chapter 2: Global spare parts inventory management** Examining academic literature of spare part business and its special features and challenges for the inventory management in the global view, inventory management impacts to net working capital and current assets, multi-echelon spare parts inventory system and its structure and functioning, the purpose of stocking and it caused inventory costs, inventory replenishment including stock types, economic reorder quantities and review policies, performance measurement including performance indicators and review practice, spare parts classification and it provided advantages to efficient inventory management, and spare parts demand forecasting.	**Output** The theoretical framework for empirical chapter and providing knowledge of the subject and possible solutions to solve the research problem.
Input Previous chapters output, company's internal documents, data from information systems and created analyzes and interviews inside the company.	**Chapter 3: Current spare parts inventory management** Exploring current process by process modeling, interviewing people, analyzing data and examining policies.	**Output** Current state analysis of case company's global spare parts inventory management including process models, policies, inventory management systems, data analyzes and understanding about reasons for the research problem.
Input Current state analysis, observed targets for development in the case company. Research problem, question and objectives of the study.	**Chapter 4: Results** Presenting created main results which provide solution to the research problem and objectives of the study.	**Output** Recommended solutions to research problem.
Input Results and other observations of study.	**Chapter 5: Conclusion** Assessing main results and evaluating further studies of the subject.	**Output** Evaluation of the main results and recommendation for further studies.

Figure 3 Structure of the study

The first chapter of the thesis is introduction where is presented the background of the study and its purpose for the case company, the case company of the study, research problem and research question, objectives of the study, the scope of study, research approach and methodology, and the structure of study. Introduction is given to understand the motives and need for study in the case company. Equally important, research approach and methodology and the structure of study are also presented in order to understand how study was carried out.

After the introduction, the theoretical chapter, “global spare parts inventory management”, forms the framework for empirical phase based on academic literature. The chapter includes a wide review to spare part business and its special features and challenges for the inventory management in the global view. In addition, inventories impacts to net working capital and current assets are investigated. Multi-echelon spare parts inventory system and its structure and function form one significant part of the theoretical chapter. The purpose of stocking and it caused inventory costs are also examined. Inventory replenishment including stock types, economic reorder quantities and review policies are studied in order to get understanding how to manage and control replenishments more efficiently and bring out what alternative systems are available in theory that could be useful to reduce excess inventory and improve material flow in the case company’s supply chain. One the major theoretical part of the inventory management is performance measurement including performance indicators and review practice has been investigated. By controlling assortment of the items, spare parts classification and its provided advantages to efficient inventory management have been studied as well. Last but not least, the academic literature review consists section about spare parts demand forecasting which is important part of the inventory and spare parts management.

After the theoretical part follows the empirical part of the study. In the chapter, “current spare parts inventory management” is described current situation regarding spare parts inventory management in the case company. There is mapped financial scenarios for the next four years related to company’s balance sheet, working capital, current assets and spare parts inventories. The purpose is to bring out and estimate what will happen if inventory management cannot be improved, this is also done to motivate development implementing. After that, there is described the spare parts supply chain in the case company and modeled the delivery process. Then, there is presented the current global inventory management system for spare parts, its structure, and system functioning in order to understand how systems work and how inventories are controlled and planned. There are also examined current performance management including key performance indicators, target setting process and follow-up practices, which are significant part of the inventory management. In addition, there are described current policies and processes, which related strongly to the inventory management in the case company. Demand forecasting is also explored, which is very important part of the spare parts inventory management. The last section of current state analysis is inventory data analysis. There are investigated current performance of inventory management by analyzing historical inventory data.

After the empirical part of the study is presented results of the thesis. There are presented main findings and solutions by answering to the research problem. In the final chapter of the study is concluded main results, findings and evaluated validity and reliability of the results. There are also presented recommendations for further studies.

2 GLOBAL SPARE PARTS INVENTORY MANAGEMENT

Inventory management is a core operation of management activity. Inventory is one of the dominant costs in many industries and supply chains. Effective supply chain management is commonly misunderstood by linking it with reducing inventory levels in the supply chain. Of course, this is a very simplistic view of supply chain management – in fact, the goal of effective inventory management is to have the correct inventory at the right place at the right time to minimize system cost while satisfying customer service requirements. Unfortunately, inventory management in complex supply chains is typically difficult, and inventory-related decisions can occur a significant impact on the customer service level and systemwide cost of supply chain. (Simchi-Levi et al. 2008, p. 30; Stevenson 2007, p. 577)

Spare parts inventories need to be available at an appropriate point in the supply chain, to provide sufficient aftersales and desired service level for customers. Especially, demand of spare parts and inventory management are complex to handle. There are the high number of parts managed, demand patterns are intermittent and lumpy, customers expect the high responsiveness due to downtime cost, and there is the risk of stock obsolescence. (Bacchetti & Saccani 2012, p. 722)

Huiskonen (2001, p.125) describes control characteristics of spare parts which are important to take into consideration for the planning and designing a spare part supply chain. Spare parts criticality, specificity, demand pattern, and value of parts effects on spare parts network structure, the positioning of material, the responsibility of control and control principles.

Inventory management consists of many sub-dilemmas. According to Happonen (2011, p. 1), one of the main questions of inventory management is how to control stock ensuring availability of spare parts efficiently. Parts do not make add value to the customer in inventory nor financial advantage for the company. The otherwise, spare parts value may decrease in the stock and additionally stored item requires resources. Simplified, companies must determine which items are most important for the operation and how they should allocate control resources, which mean they should determine what items should be kept in stock, when orders should be placed, and how much should be ordered. That also means financial aspect, spare parts in stock tie company's capital and need resources continually stocking them. Conversely, the invested capital in inventories are not available to other investments and may restrict sales growth. Thus too high inventory levels can be seen as a financial burden for the company. There is also aspect how companies should measure customer service and item movement as well as analyze costs of inventory. (Happonen 2011, p. 1; Waters 2009, pp. 335- 338)

On the other hand, in the most of the supply chains inventories cannot be avoided, because of, at some point of the supply chain is not possible to deliver products as for make to order. In some cases, the inventory response, delivery time, may even be a completely dominant factor for company success, because customers are accustomed to very short-term delivery times. Additionally, continuous changing demand poses challenges for the supply chain. Thus continuous inventory controlling has become a very challenging task to ensure the efficient operation. (Happonen 2011, p. 2)

2.1 Spare part business

In today's business world, the service business is also seen as an increasingly significant part of the whole business and the new business opportunity, and are especially coming an important part of the company's profit-making entity. Many companies have shifted their focus to improve their service business and provide more and more functions to satisfy customer's needs. In the long term, an advanced service business can ensure to a manufacturer and its service network stable, long-lasting cash flows and help to achieve good customer relations and customer confidence and loyalty. (Boone et al. 2008, p. 31; Legnani & Cavalieri 2010, p. 660)

Deloitte Consulting's survey (2013, p. 3) shows that the potential of the after-sales market has started to be gradually realized. The spare part business has seen the future business area which would be strategically important and one of the key areas for the future competition. Successful spare parts business has seen the main driver for enhancing customer satisfaction and generates repurchase opportunities for a new product. Thus can be said that spare parts operation is one of the key factors in ensuring favorable service levels for customers. At the same time when the proportion of additional sales and replacements have gradually increased, customers have begun paying more attention to the quality of aftersales services, which directly affect their purchase decisions. Thus can be stated that spare parts business will become another major revenue source for companies. However, also successfully managed spare parts operations have become an important factor when customers are making a purchase decision of the new product.

2.1.1 Definition of spare parts

Machines and technical installations have always needed maintenance and repairs because of the machine down situations, or items need to be replaced periodically. These items are called spare parts. In addition, spare parts are a vital part of the machinery and equipment in maintaining and ensuring the reliability. Common terms for these parts are spare parts and service parts. (Gopalakrishnan & Benerji 2004, p. 232; Fortuin & Martin 1999, p. 950) The spare part includes everything that needs to be replaced during the operating life of the equipment; these are for example hoses, wires, bolts, filters, engines, and gearboxes. (Gopalakrishnan & Benerji 2004, p. 232)

Botter and Fortuin (1999, p. 950) have divided spare parts into two main categories: repairable and non-repairable parts. Repairable parts can be divided into non-interchangeable and rotables parts (see Figure 4). Rotables parts are parts that can be swapped for new ones and return used part to a renovation workshop in a failure situation. However, these parts cannot be endless renovate because they wear out and repair costs will increase excessively large. Non-repairable parts, as known disposables, throwaway parts, expendables or consumables, are scrapped after removal and are replaced by a new item. So, it does not make sense from the technical and economic point of view.

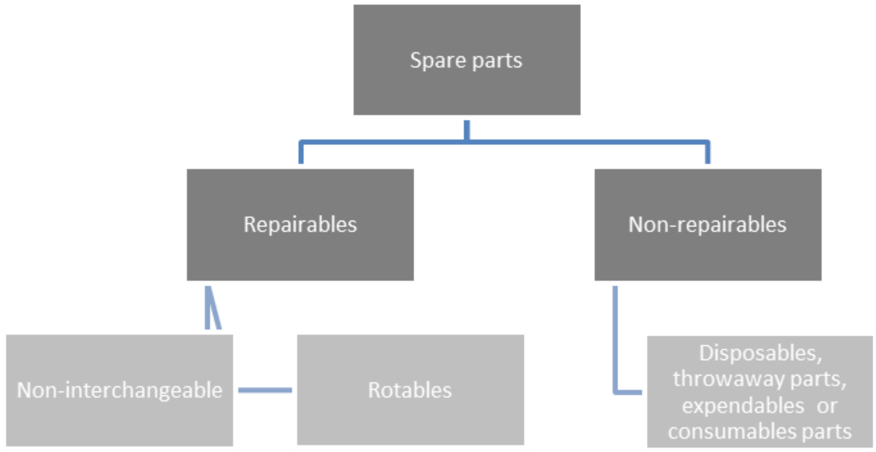

Figure 4 Spare parts segmentation by usage

Kennedy et al. (2002, pp. 202-203) have divided maintenance into two groups: preventive maintenance and unplanned repairing, which comes machine down situation. In the case of preventive and scheduled maintenance, the demand for spare parts is predictable. In this kind of situation it is usually possible to order parts just in time for use, and so it may not be necessary to stock up repair parts at all. For unplanned repair, the consequences of stock outs can cause significant costs, and some kind of safety stock policy is needed.

It is noteworthy that the service life cycle of a product is much longer than its production life cycle. This aspect is highlighted especially the case of electronic components. Fortuin & Martin (1999, pp. 950-951) mention three phases life cycle of service parts: the initial phase, the normal phase, and the final phase. In the initial phase, there are new types of parts with new technology and parts have never been used in the products before. Therefore, there is few knowledge about their failure behavior in practice. In the normal phase, demand patterns are scarce, knowledge of parts is increased, and some experiences have been gained for parts in use longer than the initial phase (Shin et al. 2012, p. 166). For fast moving items, some demand forecast may be possible. In the last phase of spare part life cycle production of the product is ramped down, however service period goes on still up to decades.

2.1.2 Special features of spare part business

Spare part availability is important for companies to ensure the efficient use of machinery and equipment. In the situation of machine breakdown, the downtime can be significantly reduced if all needed spare parts for repair are immediately available. Otherwise, the waiting time for spare parts can cause major costs because of production losses. The machine downtime can cause for example result in lost revenues, customer dissatisfaction and possible associated claims and in some cases public safety hazard. Because the capital assets are essential to the operational processes of the companies involved, downtime of the assets needs to be minimized. Downtime of the machines can be divided into diagnosis and maintenance time. Maintenance delay is caused unavailability of the required resources for diagnosis and maintenance. Therefore, it is important that the availability of spare parts is at a high level, and no delays occur. In the case of corrective maintenance, lack of the spares influences directly to maintenance delay and indirectly in the case of preventive maintenance. (Dekker & van Jaarsveld 2010, p. 1; Driessen et al. 2010, pp. 1-2.)

According to Driessen et al. (2010, p. 3) in spare part business, it is not clear how to make stocking decision for various items. In spare part inventory management is tried to find the optimal balance between spare parts availability, tied up capital and operational costs. There are tasks and decisions need to be taken into account in order to achieve the desired spare parts availability, inventory value and also minimize operational costs.

Huiskonen (2001, pp. 125-126) writes that the requirements for planning the logistics of spare parts are higher and differ from other materials logistics planning in many ways. In inventory management of spare parts, the effects of stockouts are financially remarkable but the same time the demand for parts may be extremely sporadic and difficult to forecast, and the prices of individual parts may be very high. In section 2.1.3 is described more about demand fluctuations.

Boone et al. (2008, p. 34) have studied challenges which are facing in spare parts inventory management. According to them, the following top challenges of managing spare parts are listed:

1. Lack of a system or holistic perspective
2. Inaccuracy of service parts forecasts

3. Lack of system integration among suppliers, repairers, customers, and service providers
4. Lead time deviation
5. Maintaining accurate configuration management and product revision data
6. Minimizing service parts obsolescence
7. Planning for the service requirements of aging products and the repair of aging parts
8. Planning for new product introduction
9. Maintaining repair cycle process discipline
10. Planning the location and physical distribution of service parts

Due to lack of a system or holistic perspective, Boone et al. (2008, pp. 33-36) describe that there are not enough collaborative relationships and system is viewed unilaterally. They mention this challenge has noted widely, all efforts related to service parts, from the earliest stages of product development to the design of the product support system and customer support should be based on a holistic perspective with system performance and customer satisfaction as the objective. They also emphasize the cooperation and transparency with suppliers, repairers, customers and service providers (such as service dealers). Lack of system integration leads difficulty of satisfying customers' needs. System integration between stakeholders improves transparency in the supply chain, such as demand and availability information.

Gopalakrishnan and Banerji (2004, pp. 232-233) have compared special features of spare parts to others. Besides characteristics described previously, they mentioned that spare parts demand is smaller and more uncertain – thus manufacturing has also seen uneconomical. In additional, failure data is not commonly available. They also mentioned it is very typical that in spare part supply chain there are overlapping and excessive stocks in all levels of the supply chain. Because of development and long product life cycle, spare parts standardization and identification is difficult, which causes a large variety of items. In an aspect of availability has seen many aspects such as a small percentage of different items account for large percentage of demand and the other hand stockout cost is larger than the price of the spare part.

Spare parts supply chain management is more complicated when comparing to finished products. Its unique attributes generate the complexity of the spare parts business. The life cycle of spare parts is longer than that of vehicles, and the total number of stock-keeping units is very huge. Additionally, the demand of spare parts is relatively unstable and difficult to forecast. All of the above pose enormous challenges to parts planning, purchasing, ordering, and logistics, among other operations. (Fortuin & Martin 1999, p. 949; Deloitte Consulting 2013, p. 4)

Deloitte's (2013, p. 4) survey indicates that most Chinese OEMs began to realize the importance of the spare parts business. Most managers in spare parts business area believe that factors such as investment, strategic focus, and organizational and internal communication do not constitute major obstacles to the continuous improvement of the parts business. Survey also shows that the major barriers lie in planning capabilities, the stability of parts supply, supplier collaboration, information systems, data management and supply chain visibility.

2.1.3 Demand fluctuation

Intermittent demand appears at random; sometimes there are periods having no demand at all. In the academic literature, intermittent demand has described as lumpy, sporadic or erratic demand. Typically, intermittent demand items are associated with spare parts. (Syntetos et al. 2011, p. 2) Happonen (2011, p. 27) states that demand of spare parts is the most difficult to predict. Spare parts have to be stored large quantities, which are binding a lot of capital. Sometimes there is no demand at all and sometimes occur individual large demand spikes. He also states that the spare parts delivery times vary significantly from product to product and even in same spare part between different orders. Regarding the spare parts, it can be said that the demand is largely stochastic and customers cannot estimate spare parts need by quantity or date. Also Willemain et al. (2004, p. 375) state that intermittent demand, which refers to demand with a large number of zero values, makes difficult to manage the spare parts supply chain. Demand is also lumpy which refers to the great variability among the non-zero values. Happonen (2011, p. 119) has solved demand fluctuation problem by chosen two parameters which occur the nature of demand and they are easy to understand and measure. These parameters are 1) quantity demand fluctuation and 2) demand fluctuation of the period. These two parameters can create four very distinct demand classes. Categorization makes possible to use optimal inventory policy for each item group. He has divided intermittent demand to four categories (see Figure 5):

1) Occasional and erratic demand, but not periodic
2) Peaky demand
3) Regular demand
4) Slow or seasonal demand.

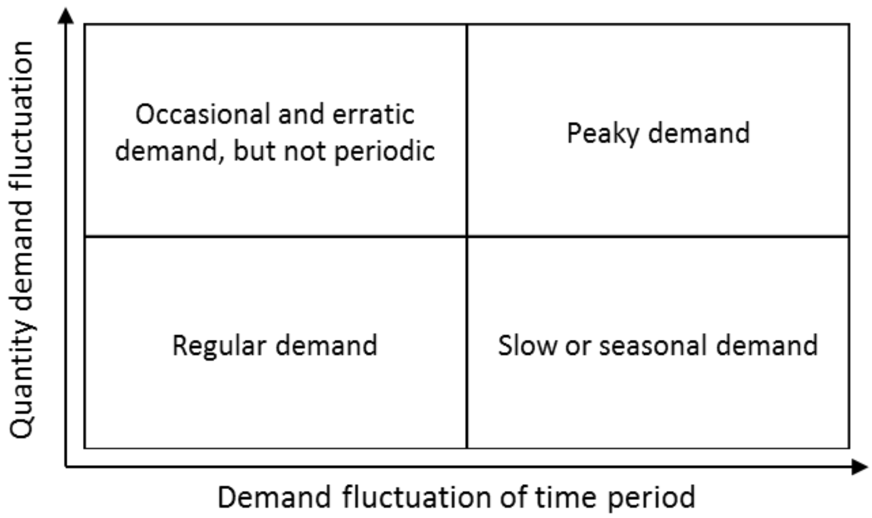

Figure 5 Categorization of different demand profiles (*Adapted from Happonen 2011, p. 119*)

2.1.4 Bullwhip effect

Spare part sales offices have to maintain customer satisfaction and therefore keep service level at a high level. Because of this managers need to predict the future demand and if it differs from forecasted value, then inventory levels also fluctuate. This uncertainty and fluctuation cause increasing need for safety stocks. Demand fluctuation may be bringing about demand forecasting error at the upstream of the supply chain and it affects larger for upper echelons. This kind of effect is called bullwhip effect. Forecast methods can reduce this phenomenon and its impact. (Lee et al. 1997) In section 2.9 describes more about demand forecasting.

Frontline customer demand fluctuation and needed safety stocks are not the only reason why the bullwhip effect occurs. Hoppe (2006, p. 97) states the three leading causes of the bullwhip effect; safety-conscious attitude in the supply chain management and not existing harmonized order quantities and processes. On the other hand, there are low forecast accuracies. Thus, the safety stock requirement increases because uncertainties and planning variances must be compensated with increased stocks to maintain availability at a high level.

Also, other researchers have identified major causes of the bullwhip effect. Updating demand forecast affects to order quantities increasingly and causes at the upstream of supply chain need to readjust demand forecast as well. The reason is that for upstream operations get a signal from order placing, this lack of centralized information causes uncertainty at the upstream level and they increase safety stock levels by ordering as well, then data is duplicated during to the supply chain. This effect can be reduced in multi-echelon inventory systems by improving transparency of the supply chain, for instance showing actual demand information from the downstream of the supply chain to upstream and using continuously updated demand forecasting. (Lee et al. 1997; Simchi-Levi et al. 2003, pp. 23-24)

Firms use batch ordering to minimize fixed ordering costs, and they want to optimize transportation costs to take advantage of transportation discounts, for example, full truckload quantities. Batch ordering is commonly used in items of a low purchasing price. Batch ordering may lead to a distorted and highly variable pattern of orders – some weeks have larger orders and some no orders at all. The batch ordering involves price fluctuation also; retailers often attempt to stock up when purchasing prices are lower. (Lee et al. 1997; Simchi-Levi et al. 2003, pp. 23-24)

Increased lead time of delivery has also seen problematic. Lead time variability increases uncertainty, thus longer lead times and a small change in the estimate of demand variability causing demand fluctuation during lead time. Increased lead time implies a significant change in reorder level, leading to a significant change in order quantities. This, of course, leads increasing safety stock and variability. (Simchi-Levi et al. 2003, p. 23)

Inflated orders affect bullwhip effect. If sales offices suspect that a certain product will be in short supply, sales offices will anticipate receiving supply proportional to earlier ordered. Then they order larger amounts to avoid stock outs. When the period of the shortage is over, they go back to order standard quantities. (Lee et al. 1997; Simchi-Levi et al. 2003, p. 24)

Kalchschmidt et al. (2003, p. 398) state that globally centralized inventory control implies that visibility on demand, costs and inventory status of all the locations are in the system. Conversely, decentralized information implies that each location sees their own demand only and the information is not provided along the supply chain. According to their research, demand fluctuation due to that the regular demand comes from many small customers and an irregular demand from a few large the largest customers. They recommend gathering demand information from largest customer beforehand such as forecast.

The bullwhip effect significantly affects inventory levels, which increases the invested capital in warehouses. Companies can cope with the bullwhip effect with reliable and centralized information. When end customer demand information is transparency for the whole supply chain, and it is available for each echelon of the supply chain, the impact of the bullwhip can be significantly reduced but does not eliminate it entirely. For standard components are used a vendor-managed inventory (VMI) to reduce the bullwhip effect. For example, in vendor-managed inventory, the manufacturer or supplier manages the inventory of its product at the retailer store and therefore determines for itself how much inventory to keep on hand and how much to ship to the retailer in every period. (Simchi-Levi et al. 2003, pp. 25-26)

2.2 Net working capital and current assets

Net working capital is money used to finance ongoing operations (Krajewski et al. 2013, p. 386). According to Arnold (2013, p. 510), net working capital is the investment a company makes in assets which are in continual in use and are turned over many time in a fiscal year. More theoretical, net working capital is defined as the difference between current assets and current liabilities (see Figure 6). In financial reports, net working capital is calculated by the following formula:

$$Net\ working\ capital = current\ assets - current\ liabilities \qquad (1)$$

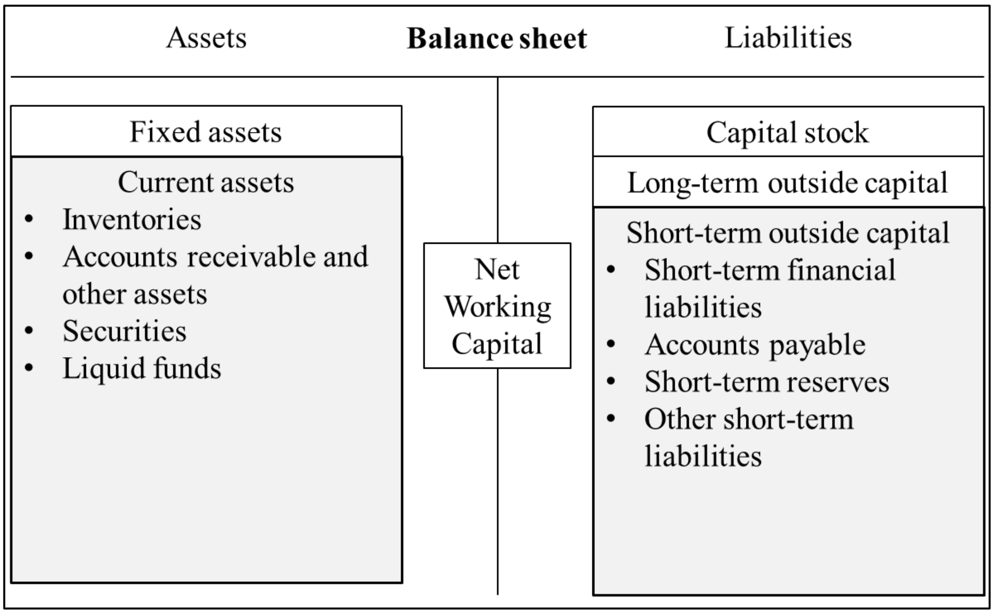

Figure 6 Net working capital on the balance sheet (*Adapted from Hofmann et al. 2011, p. 14*)

According to Masson and Krawczyk (2010, p. 30), working capital management has a significant role in cash management. Many times the primary cause of an enterprise's failure is poor and unsuccessful working capital management. Working capital measures how well a company manages its liquidity, how much capital is tied to business thus it also measures the efficiency of liquidity management. Managing working capital is an important day-to-day activity, which ensures that company has sufficient resources to continue its operations. According to Ross et al. (2005, p. 43) and Gitman (2009, p. 21) objective of working capital management is minimizing the cash conversion cycle and the amount of capital tied up in the company's enterprise process, in practice reducing current assets and extending current liabilities. The purpose of working capital management is significant for managing company's business successful, sustainable and it has a direct impact on performance.

In additional to net working capital, there is the cash-to-cash cycle concept, or also called cash conversion cycle (CCC), that is one possibility for measuring and controlling the effectiveness of working capital management. The cash-to-cash cycle comprises the period between invested money in raw materials and received cash from the customer (see Figure 7). (Hofmann et al. 2011, p. 14)

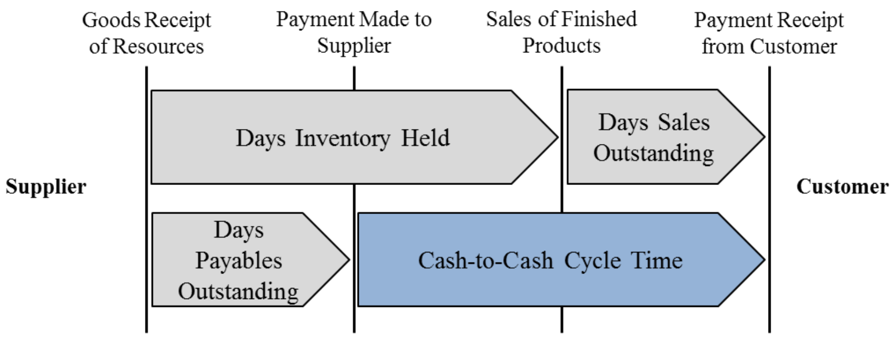

Figure 7 Cash-To-Cash Cycle time based on the flows of goods and payments (*Adapted from Hofmann et al. 2011, p. 14)*

Longer conversion cycle means more investment in working capital. Minimizing cash conversion cycle to a reasonable minimum level normally leads to improved profitability. (Deloof 2003, p. 574) Cash-to-cash cycle time (CCCT) can be calculated as following:

$$CCCT = Days\ Inventory\ Held + Days\ Sales\ Outstanding - Days\ Payables\ Outstanding \quad (2)$$

Corporate's current assets are meant working capital, which is tied up to raw materials, finished products and work in progress inventories and goods and equipment which are needed to produce them. According to IFRS (Interpretation Committee Meeting 2010, p. 2) financial report standard, IAS 16, bigger and longer life cycle spare parts can be considered the part of working capital, if spare part can be used only in connection with an item of property, plant, and equipment, they are accounted for as property, plant, and equipment. Thereby spare parts and servicing equipment are usually carried as inventory and recognized in profit or loss as consumed.

There are many similarities with inventories and current assets to corporate's financial and real processes. A good current assets management sustains production cycle, and it can also reach good profitability for the company. Affecting the profitability of the basic factors includes the company's net sales, cost level and amount of tied capital to inventories. (Faden 2014, pp. 3-5) The company capital installment, inventories are usually the least productive. Particularly during the economic downturn enhancing its management is emphasized because companies are harder to get loans at affordable prices. Company size and business sector affect the amount of needed current assets. In additional, third parties such as investors, current assets financiers, and suppliers, are interested the financial performance related current assets management.

2.3 Multi-echelon spare parts inventory system

Nowadays in many globalizing industrial sectors, companies are dealing with demand, which is more and more uncertain often due to the supply chain structure. Demand uncertainty causes the critical effect to the simultaneous increasing inventories and decreasing customer service. (Kalschmidt et al. 2003, p. 397) The global industry is one of the most characterized by complex systems which require high levels of backups to comply with availability requirements. For global business and customers, a multi-echelon structure is a standard requirement: organizations control many sites worldwide with different targets and competencies. Usually, in the global business, it is reasonable to keep items stored in locally, ensuring high availability for important spare parts. Considering the failure rate of the items and its impact for customers business and their satisfaction, it is described that most components have both a strategic and a high economic value and the problem of minimizing inventory costs, assuring at the same time a high availability is crucial. Even if a large number of spare parts increases holding costs in warehousing process, also they will tie invested capital to inventories. Also good to notice that every single shortage impact to customer satisfaction. Multi-echelon system is done to service customers and gives a high response time. In this case, it is important to see that spare parts demand varies a lot between sites. Thus, the stocking decision is regarded for spare part allocation, which should consider stock availability both for central warehouses and local sites. (Costantino et al. 2013, pp. 96-97)

The main idea of multi-echelon structure is that central warehouse replenishes stock of local branch warehouses. Figure 8 presents a simple example of the multi-echelon inventory system. Outside suppliers replenish central warehouse. Inventory management in this system is complex because demand at the echelon of the central warehouse is dependent on the demand at the branch warehouses and finally demand of customers. Stocking decisions in branch warehouses affect demand profile in the central warehouse. (Silver et al. 1998, p. 475)

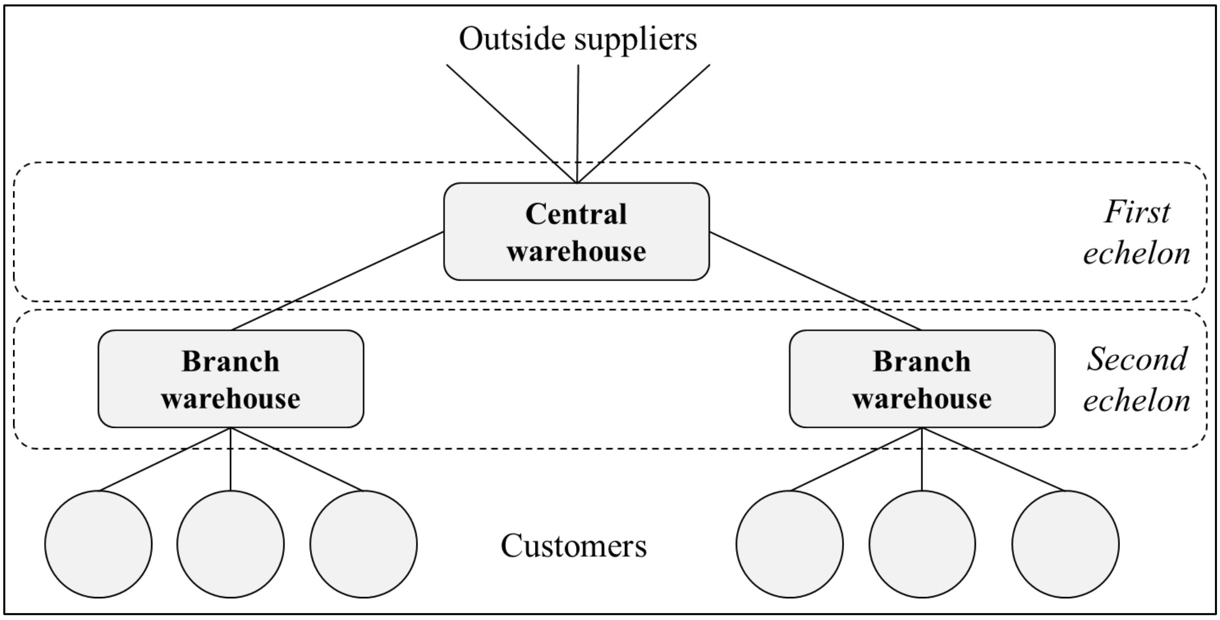

Figure 8 An example of multi-echelon inventory system (*Adapted from Silver et al. 1998, p. 475*)

According to Paakki et al. (2011, p. 166) and Huiskonen (2001, p. 126) to achieve agile, cost saving and efficient supply chain, the primary focus should be on managing and controlling the whole spare part supply chain rather than controlling and managing individual echelons and inventories. In order to create an efficient supply chain, have to improve open information systems and develop collaboration along the supply chain.

Lee (2004) describes that successful companies do not try to adapt to changes in their supply chain but try to change its themselves. If companies are not proactively controlling and managing supply and demand variabilities, the variabilities are taken as given from the supply chain, and inventory management has to adapt to the environment's constraints passively. Therefore, is created a situation where the successfulness of inventory management is determined by other parties of the supply chain (see Figure 9). From the service point of view, a reactive management can be successful if the company's inventory management is performing well. Nevertheless, this can become costly for the whole supply chain. The optimization of a single stocking echelon in a large distribution network leads sub-optimal results for the whole chain. Actually, this kind of operating decreases the whole supply chain's performance and efficiency. For example, an individual sites' replenishment behavior in their benefit leads that demand type change from stable to unstable in the distribution center. Because a company can only control the variability in their internal processes, when reactive management demand and supply variability are not in control it will lead a lack of controlling and cause sub-optimization of own processes. In additional, it is not sufficient if there is a pressure to increase supply chain performance without generating excessive inventory levels and costs. (Paakki et al. 2011, p. 166)

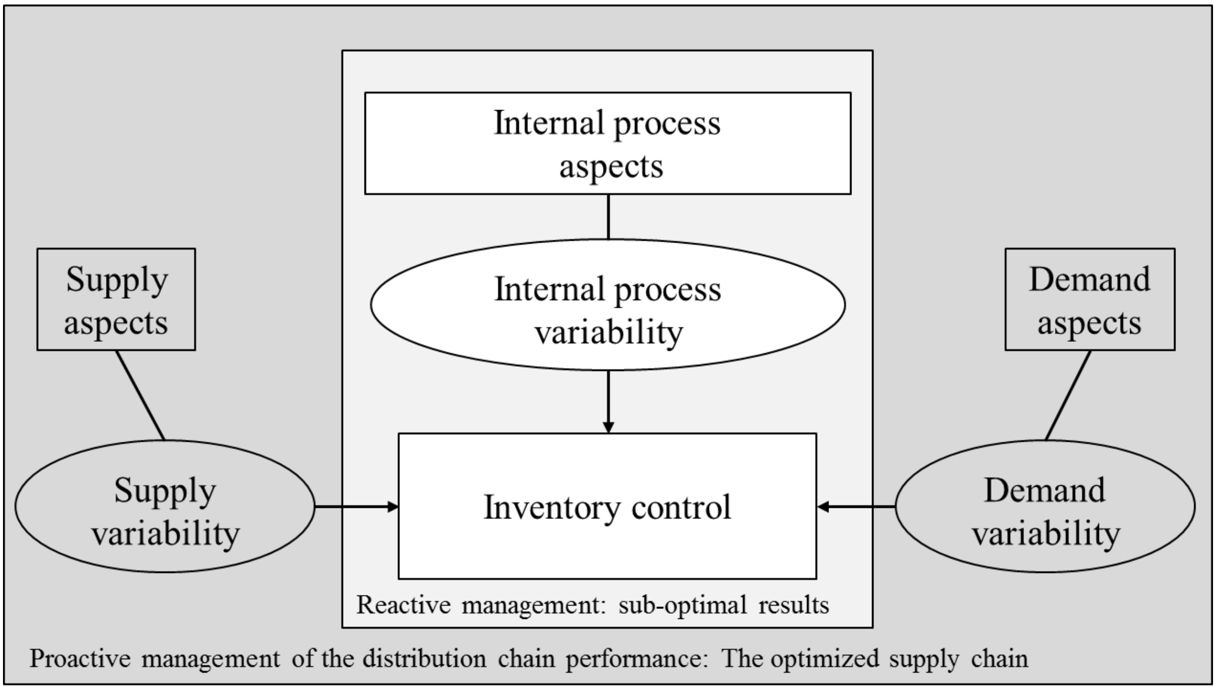

Figure 9 Three aspects of the inventory management (*Adapted from Paakki et al. 2011, p. 166*)

For proactive management of the distribution chain performance, the role of supply chain management should be focused to reduce demand and supply variability (see Figure 10). The proactive management means simplified that the scope of the inventory management has to expand to cover supply and demand management aspects and to the internal inventory control processes. (Paakki et al. 2011, p. 166)

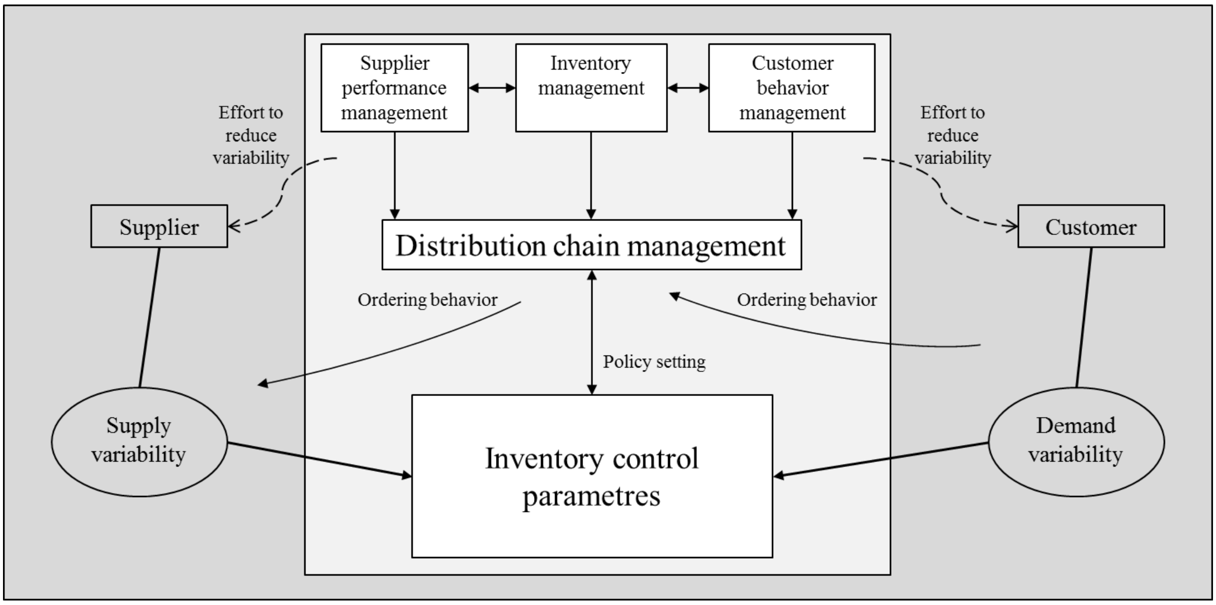

Figure 10 Inventory management's expanded role as a distribution chain management (*Paakki et al. 2011, p. 166*)

The multi-echelon inventory system is not entirely unproblematic and complete to function effectively. Silver et al. (1998, p. 487) define that the system has three serious flaws. The customer is dependent on whether the branch warehouse has sufficient stock to fill the order. If the stock is not available, the lead time could be as long as branch warehouse's lead time plus transportation time to end customer. So, lead times duplicated in the case of stockouts. Second thing, the multi-echelon system ignores the cost implications at one echelon of using certain ordering logic at another echelon. The third point is that the system may be caused bullwhip effect along the upstream of the chain, because even if customer demand is fairly smooth, the orders placed by customer become progressively larger, affect more fluctuation and less frequent when moving to the upstream.

2.4 Purpose of stocking

Spare part logistics has an inherent difficulty: common models for inventory management are invalid, as the demand process is different and demand data is scarce. Ideally, materials move smoothly and continuously through a supply chain. In reality, there are always delays – and when materials stop moving, they form stocks. Simplified, organizations hold stocks to give a buffer between variable – and uncertain – supply and demand. Imagine an item being delivered to a warehouse. Suppliers have delivered in large quantities, but those items are sold in much smaller quantities to customers. Then stock is replenished with every delivery and is reduced over time to meet demand. Thus the stocks give a cushion between supply and demand. Stocks allow the shop to continue working efficiently, even when deliveries are delayed, or there is unexpectedly high demand from customers. Inventories also allow operations to continue smoothly and avoid disruptions. (Waters 2003, pp. 252-253)

Waters (2003, p. 254) has presented more specific the purpose of stocks:

- act as a buffer between different parts of the supply chain
- allow for demands that are larger than expected, or at unexpected times
- allow for deliveries that are delayed or too small
- take advantage of price discounts on large orders
- allow the purchase of items when the price is low and expected to rise
- allow the purchase of items that are going out of production or are difficult to find
- allow for seasonal operations
- make full loads and reduce transport costs
- give cover for emergencies
- can be profitable when inflation is high. (Waters 2003, p. 254)

Huiskonen (2001, p. 126) describes the purpose of storage for companies is to create sufficient service level as low as possible invested capital to inventories and low-level managing costs. According to Sakki (2009, p. 103) storing and logistic are functional opposites of each other in logistic-process. It is meant that by the larger quantity of shipments, reduced transport unit cost. On the other hand, the bigger shipments increasing the need for storing. This induces inventory costs but storing is needed because of long distances and transportation. It is worth noticing that the repeated transport of small quantity of items will be expensive. There is one of the main purposes to find a suitable balance of these aspects.

2.5 Inventory costs

Managing spare part inventory is an important task for supply chain operations because spare parts tied up an enormous amount of capital (Syntetos et al. 2009, p. 292). Stocks management involves a number of costs which must be taken into account in inventory management, particularly in the spare parts inventory management because of their specific features differ a lot, for example, from the production stocks. Stevenson (2007, pp. 547-548) describes three basic costs which are associated with inventories. There are holding cost, ordering cost and shortage cost. Holding cost refers to the cost to carry an item in inventory; ordering cost including the costs of ordering and receiving inventory, and shortage cost results when demand exceeds the supply of inventory. These cost items are described next.

2.5.1 Holding costs

Inventory holding cost is the expense associated with carrying an item in inventory for a length of time, usually a year. These costs include interest, insurance, taxes, depreciation, obsolescence, deterioration, spoilage, pilferage, breakage and warehousing costs such as heat, light, rent, labor and security. Holding costs are stated in two ways: as a percentage of unit price or as a capital of amount per unit. Total inventory expense is calculated by multiplying average inventory level by annual inventory carrying cost rate. In that case, commonly is used purchase costs rather than selling values. (Buker 2001, pp. 1090-1091; Bowersox et al. 2002, p. 289; Stevenson 2007, p. 547; Vollmann et al. 2005, p. 138)

Stevenson (2007, p. 548) states that typical annual holding costs vary typically between 20 and 40 percent of the item value, but inventory management policy determines the exact holding cost used by a company. Usually, the percentage value of holding cost is used in inventory planning systems. According to Waters (2003, p. 256), the total of holding cost is typically around 25 % of stock value a year. Inventory holding cost consists of the costs presented in Table 1. It is difficult to give exact values for these because the costs can vary widely between companies and business areas. Thus, the percentages in the table are only guidelines for holding costs.

Table 1 Annual holding costs as a percentage of unit cost (*Waters 2003, p. 257*)

Component	***% of unit cost***
the cost of money	*10-15*
storage space	*2-5*
loss and obsolescence	*4-6*
handling	*1-2*
administration	*1-2*
insurance	*1-5*
Total	*19-35*

2.5.2 Ordering cost

Ordering costs are the costs of ordering and receiving inventory, these costs vary with the actual placement of order. Reason for this is the ordering costs are typically expressed as a fixed monetary amount per order. Thus the size of the order does not effect on the cost per order. Ordering cost includes shipping, preparing invoices, inspecting of goods upon arrival for quality and quantity, moving the goods to temporary storage and other handling costs. In practice, the best estimate for a reorder cost often comes from dividing the total annual cost of the purchasing department by the number of orders it sends out. Worth to notice that ordering cost differs from the purchasing cost which means the cost of goods (COGS). (Stevenson 2007, p. 548; Waters 2003, p. 256)

2.5.3 Shortage cost

A final set of inventory-related costs consists of incurred cost when demand exceeds the available inventory for an item. According to Vollmann et al. (2005, p. 139) in some cases, shortage costs may equal the product’s contribution margin when the customer can purchase the item from competing firms. In other cases, it may involve only the paperwork required to keep track of a back order until a product becomes available. Waters (2009, p. 342) state that the special arrangements include expenses caused by remedial actions. These actions can be expediting replacement orders, making emergency orders, paying for special deliveries, and utilizing more expensive suppliers. Ballou (2004, pp. 339-340) divides these shortage costs to a lost sales cost and a backorder cost. He states that tangible costs, which come from order processing, such as additional transportation and handling costs, in the case of backorders, are not difficult to measure. Intangible cost of lost future sales is very difficult to measure.

It can be difficult to get figures for any inventory costs, but shortage costs are a particular problem. Shortage cost includes so many intangible factors that it is challenging to determine a reasonable value for the cost. In generally, shortages are expensive, so it is reasonable to avoid them. In order to avoid the relatively greater stockout costs, companies are more willing to pay costs of holding inventory. Unfortunately, this kind of approach tends to grow inventory levels especially in the case of uncertain demand when company's capital is more and more locked. (Stevenson 2007, p. 548; Waters 2003, p. 257)

2.6 Inventory replenishment

Inventory replenishment is one of the key issues in global inventory planning. To understand inventory management in the bigger picture the subject of inventory replenishment is mandatory to internalize. In this section is discussed about stock types, reordering and different types of inventory review systems.

2.6.1 Stock types

Safety stock is the amount of inventory kept on hand to allow for the uncertainty of demand and the uncertainty of supply, they are maintained to protect against demand and performance uncertainty. Safety stocks are not needed if the future rate of demand is known and delivery time are known certainty. However, in a real situation, this is not known with certainty. Thus that average level of stock is used to protect against stockouts before next replenishment arrives. Safety stock can be seen as additional stock which is carried to decrease the risk of stockouts during the lead time. Safety stock protects against deviation of delivery date variances. So, the safety stock depends on the replenishment lead time, which is time between order placing and receiving. In additional, the amount of safety stock protects against various deviation of requirement, which is usually known as forecast inaccurate. The level of safety stock is controllable, and this investment is directly related to company's set desired level of customer service, which is the third factor for safety stock. (Silver et al. 1998, p. 31; Hoppe 2006, pp. 257-258)

A sufficient safety stock can be determined by using the historical frequency of demand data on calculation. Probability is based on the random chance of an occurrence within a large number of occurrences. The probability of occurrences is assumed into a distribution pattern around the average value of all occurrences. The most used a number of the frequency distribution for inventory control is the normal distribution, which is characterized by a symmetrical bell-shaped curve. (Bowersox et al. 2002, p.300) The normal distribution is illustrated in Figure 11.

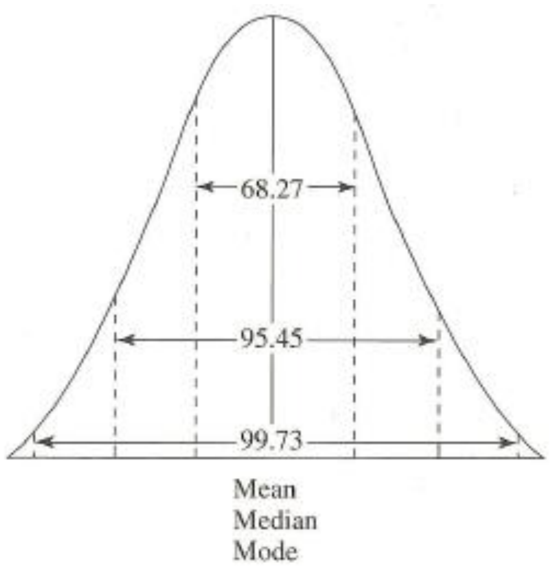

Figure 11 Normal distribution curve (*Bowersox 2002, p. 300*)

Standard deviation is known basis of using a normal distribution for predicting demand during order lead time. The standard deviation describes the dispersion of events within specified areas under the normal curve. Within ±1 standard deviation, 68,27 percent of all events occur. For instance, 95,45 percent of the days during order lead time will experience daily sales within ±2 standard deviation of the average daily sales. Therefore, with higher standard deviation, more events occur in the time period. The calculation of the standard deviation is the first step to set up safety stocks. (Bowersox et al. 2002, p.300) The standard deviation is determined as following:

$$\sigma = \sqrt{\frac{\sum F_i {D_i}^2}{n}} \tag{3}$$

where

σ= Standard deviation

F_i= Frequency of event *i*

D_i= Deviation of event from mean for event i

n= Total observations available. (Bowersox et al. 2002, p.300)

When the standard deviation is continuously followed up, a quantity of safety stock can constantly be adjusted. Thus, a material planning system can change order point by demand fluctuation. However, always remember that safety stock adjustment is only one way to protect the security of supply. (Sakki 2009, p.122)

The size of the safety stock depends on the desired service level. If demand varies a lot, the standard deviation of lead time demand is high and to ensure a high service level safety stock is needed (Waters 2003, p. 268). According to Silver et al. (1998, p. 255), the standard deviation is used for calculating safety stock. Following formula determines required quantity of safety stock:

$$SS = k \times \sigma_L \tag{4}$$

where

SS= Safety stock in units

k= Safety factor

σ_L= Standard deviation of lead time demand.

Sakki (2009, p.122) presents a formula to determine safety stock by using standard deviation. Following formula can be used when lead time demand is normally distributed other way:

$$SS = ks\sqrt{L} \tag{5}$$

where

SS= Safety stock in units

k= Safety factor

s= Standard deviation of lead time demand

L= lead time, delivery time.

Safety factor (k) determines the probability of a stockout for the item. The safety factor depends on the stockout risk that company accepts. Generally, the smaller the risk the company is willing to accept, the greater safety factor value. (Stevenson 2007, p. 565) On Table 2 is presented values for desired service level corresponding to the safety factor. Figure 12 represents the connection between desired service level, stockout probability and safety factor.

Table 2 Desired service level corresponding to safety factor

Desired service level (%)	50,00	75,00	90,00	95,00	97,00	98,00	99,00	99,50	99,90	99,99
Safety factor (*k*)	0,00	0,67	1,28	1,64	1,88	2,05	2,33	2,58	3,09	3,72

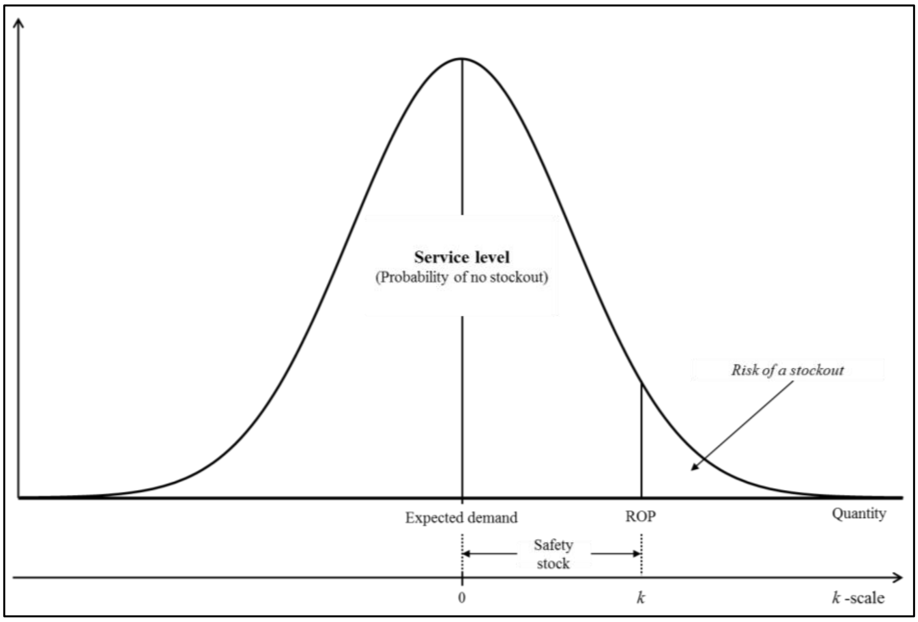

Figure 12 Connection between desired service level, stock-out probability and safety factor.*(Adapted from Stevenson 2007, p. 565)*

As can be seen the connection between safety stock and service level is obvious. When providing high service level it affects the size of safety stock. This is because the safety stock is determined to secure the availability of items during lead time. If stockout risk is wanted to avoid then safety stock is higher due to high safety factor.

2.6.2 Reorder quantity

Such has been stated the management has to determine two functions about inventory management: which part to keep in the stock and when and how much to order items. Order quantity determines how much will order in every order cycle. A lot size has the remarkable impact of cost management in inventories. It balances inventory holding cost with the cost of ordering. Therefore, the greater the order quantity, the larger the average inventory value, consequently, the greater annual holding cost. On the other hand, when ordering the larger order quantity then fewer orders required per planning period and, thus the total ordering cost is lower. An optimal order quantity is where holding and ordering cost is lowest for a given sales volume. Figure 12 illustrates relations between these aspects; the main objective is identifying the ordering quantity that minimizes the total inventory holding and ordering cost. (Bowersox 2002, p. 292)

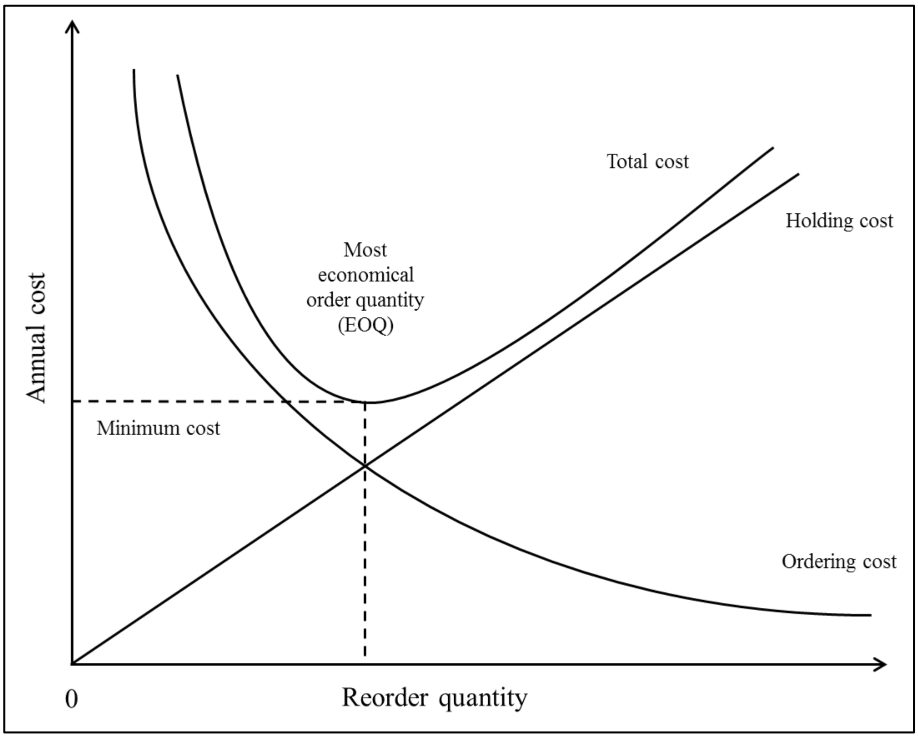

Figure 13 The lot size increases, the stock, and its costs are increasing, but fewer receiving incur fewer expenses. Optimum order size, which is economical order quantity, can be found at the intersection of cost. (*Adapted from Bowersox et al. 2002, p. 292; Sakki 2009, p. 117*)

The economic order quantity, which is also known as optimal reorder quantity and Wilson formula, is Ford Harris' development order quantity determining method. The basic assumption is kept that demand is independent and constant. Also, lead time does not affect to productivity and costs are fixed. To determine EOQ, ordering and holding cost need to be known. (Happonen 2011, p. 23)

According to Bowersox et al. (2002, p. 293), the standard formulation for determining EOQ is:

$$EOQ = \sqrt{\frac{2C_oD}{C_iU}} \tag{6}$$

where
EOQ = Economic order quantity
C_o = Cost per order
C_i = Annual inventory holding cost
D = Annual sales volume, units
U = Cost per unit (purchasing value).

Happonen (2011, p. 23) observes that the method gives easily distorted control information when the assumptions do not practically realize. He notes that the method suffers from changing demand of the item. The changing demand should not be even fast changing, in that case the formula controls the operations too late and it not integrates to real demand. Thus, it would be more reasonable to use short-term demand data or use the method for stable demand items only. However, advantages of the method are easy to understand, it is commonly used and it is also easy to implement and extend, thus the whole supply chain is often used it.

2.6.3 Continuous review policy

The previous section responded to question of order quantity. Second major question about inventory control is: when should order to be placed? According to Krajewski et al. (2013, p. 339), spare parts have independent demand. Managing independent demand inventory can be tricky because external factors influence to demand. At following will be defined review systems which work well with independent demand items.

A continuous review system, which is sometimes called a reorder point (ROP) system, tracks continuously remaining inventory and when the amount of quantity of hand reaches a predetermined minimum stock level, which is also called as reordering point, a fixed amount of items will be ordered. In practice, inventory level is managed continuously by the system.

Simplified, the goal in ordering is to place an order when inventory on hand is sufficient to satisfy demand during lead time. The quantity is determined by four factors which are the rate of demand, the lead time, the variability of demand or lead time, which protect from uncertain demand and deviation of delivery time and desired service level. (Krajewski et al. 2013, p. 340)

Continuous review policy is an inventory review system where a fixed quantity is ordered when on hand quantity drops to reorder point or below. The inventory position measures ability of the stock units to satisfy future demand. It includes scheduled receipts (open orders), orders which are ordered but not yet received plus available stock (on-hand) minus backorders. The following Figure 14 illustrates the function of the continuous review system. (Krajewski et al. 2013, pp. 339-340)

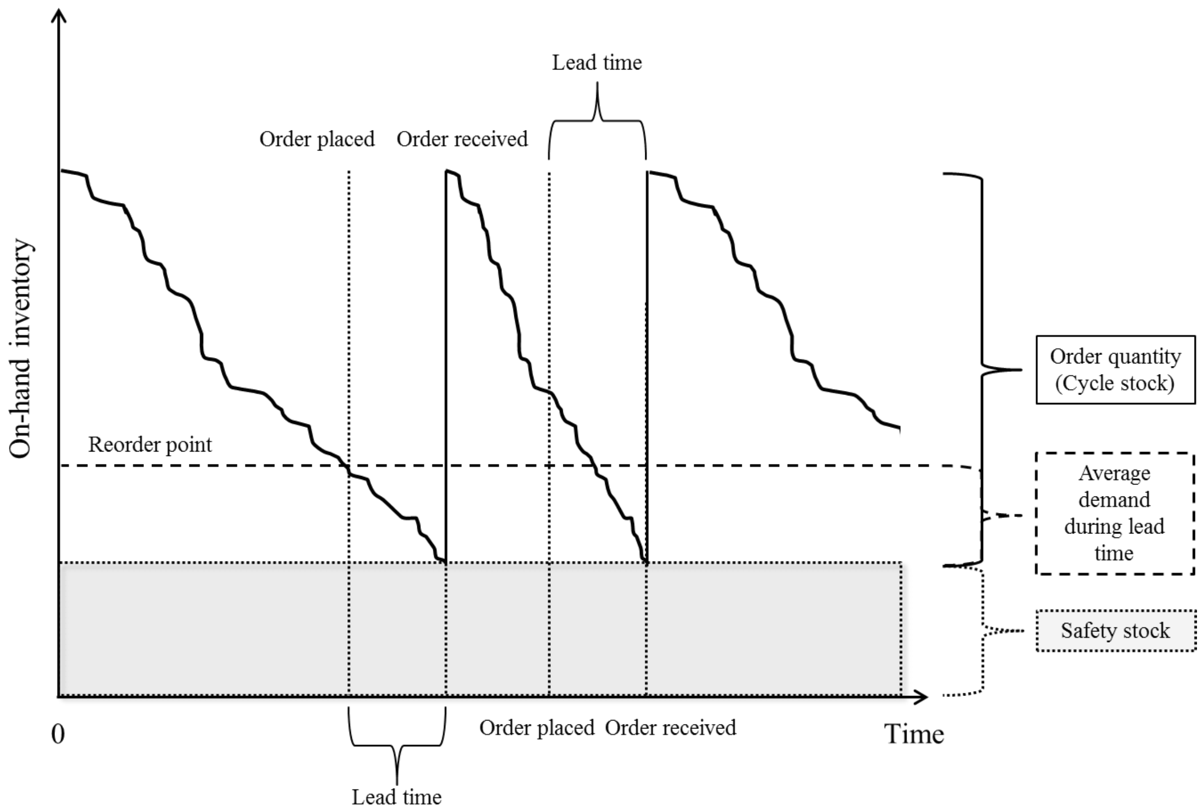

Figure 14 Simplified reorder point (ROP) system, when demand is uncertain (*Adapted from Krajewski et al. 2013, p. 341*).

According to Bowersox et al. (2002, p. 292; 309) when uncertainty exists in either demand or performance cycle length, safety stock is required, then reorder point can be determined by following formula:

$$ROP = D \times T + SS \tag{7}$$

where

$ROP =$ Reorder point in units

$D =$ Average daily demand in units

$T =$ Average performance cycle length in days

$SS =$ Safety stock in units

2.6.4 Periodic review policy

An alternative inventory control system is periodic review system, which is sometimes called a fixed interval reorder system. In this system item's inventory position is reviewed periodically. A new order is placed after each review, the interval between orders is fixed. A lot size of orders can differ because of demand variability. For instance, the order can be placed weekly or monthly, and the stock will replenish every time to the target inventory level. The following Figure 15 shows the function of the periodic review system. (Bowersox et al., 2002, p. 310; Krajewski et al. 2013, p. 345)

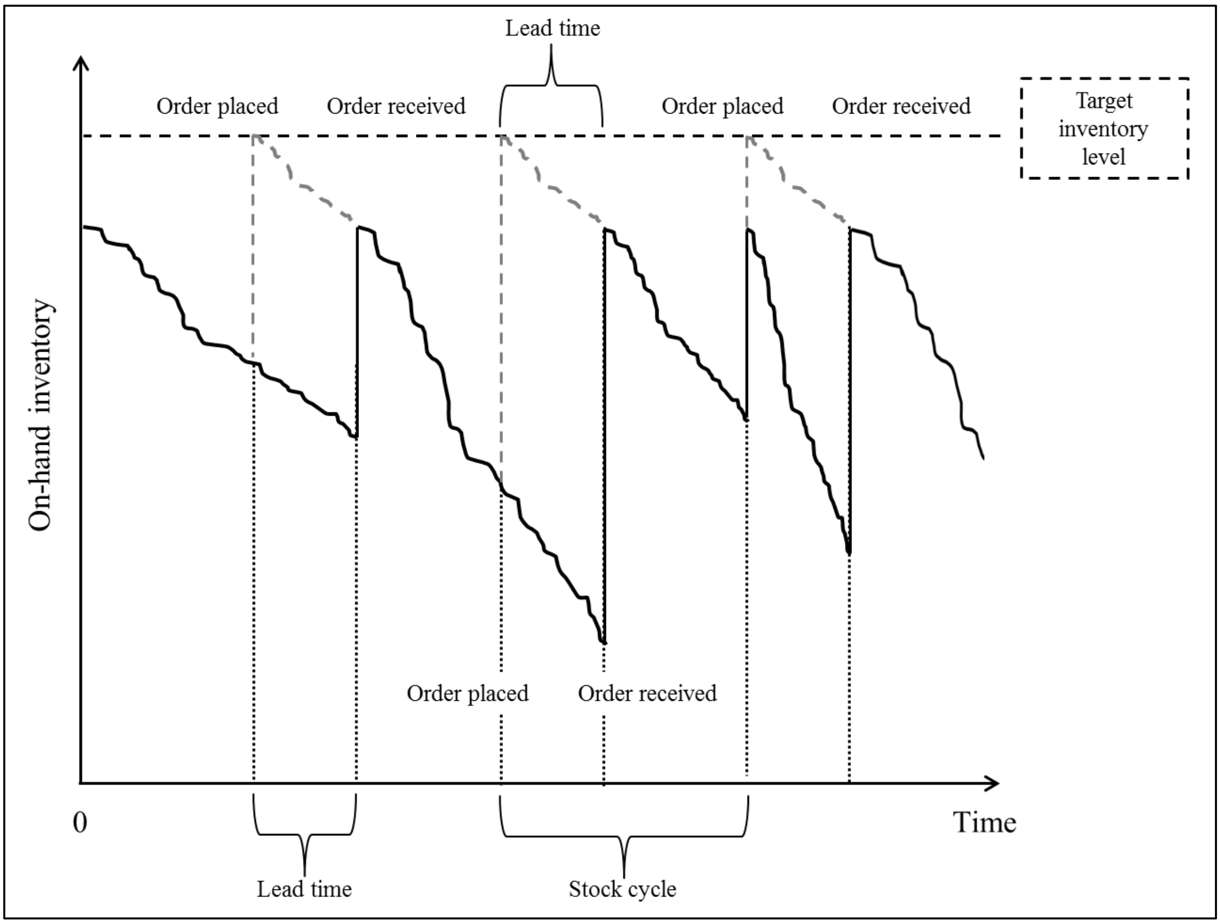

Figure 15 Simplified periodic review system, when demand is uncertain (*Adapted from Krajewski et al. 2013, p. 345*)

When periodic review system will be taken use, managers must make a decision about the length of time between reviews and the target inventory level. One and the simple way is to make a decision that for instance, every Friday is ordering day. Another way is to calculate fixed interval between orders by using the cost trade-offs of the EOQ. That means time can be calculated average time between orders for the economic order quantity. Though a demand can be variable; some orders will be larger than calculated EOQ or smaller, the average lot size should be close to the EOQ. (Krajewski et al. 2013, p. 346)

The target inventory level, when demand is variable and lead time is constant, is an important factor when using period review system. Waters (2003, 273) and Krajewski et al. (2013, p. 347) define target stock level supposing the lead time is constant. Order must be placed when the stock on hand plus current order must last until the next order arrives. By assuming that the demand for each period is normally distributed that the both the order period and lead time are fixed. Then following formula is determined that the target stock level is mean demand over the order period and lead time plus safety stock for the protection interval:

$$Target\ inventory\ level = D(T + L) + SS \tag{8}$$

where

$D =$ Mean demand

$T =$ Stock cycle

$L =$ Lead time

$SS =$ Safety stock.

Otherwise, if target inventory level is determined and stock on hand is known then reorder quantity is calculated as (Waters 2003, p. 272):

$$Reorder\ quantity = target\ inventory\ level - stock\ on\ hand \tag{9}$$

Because replenishments are made at fixed intervals, the system allow for standardized pickup and delivery times. Also in some cases, if multiple items come from the same supplier, grouping the orders leads reduced ordering and transportation costs because shipments can be combined. In additional periodic review system does not need to be known continuously, it may be practical approach if inventory position cannot be closely monitored. On the other hand, periodic review system is dependent on the safety stock because of the need to protect against stockouts during order interval plus lead time. This may lead to increased invested capital to inventory and holding cost. (Krajewski et al. 2013, p. 346; Stevenson 2007, p. 573)

According to Krajewski et al. (2013, p. 349), there is also possible to use combined inventory control systems where are merged some features of continuous and periodic review systems. Optional replenishment system is used to review the inventory position at fixed intervals, if stock level is dropped to predetermined level, or below, to place a variable-sized order to cover expected needs, typically to inventory target level. Other continuous review system based hybrid system issues a replenishment order each time a withdrawal is made for the same amount of the withdrawal. This leads to more orders are placed, but orders are smaller. This review system is especially suitable control policy for expensive items, and no more inventory is held.

2.7 Performance measurement

When the supply chain is designed and planned it might feel that system is fixed, but in real it continues to evolve. Without measurement, it is not easy to say how well it works and how it can be improved. The performance of supply chain should be measured all the time. If it is not measured, it is not possible to say how it is doing, whether it improved or is it getting worse, or are targets met, either compare to others. There are many reasons why it is reasonable to measure performance and productivity. Measuring is done because there is desired to ensure customer satisfaction and uphold a culture of continuous improvement within the operation. By measuring can discover potential issues before they will escalate major problems. It is said, “What you can’t measure, you can’t manage.”. Very common problem is usually what to measure and how should measure it. There are many possibilities to measure the performance of supply chain. Some of these are indirect measures and often relate to finance. Financial measures are usually easy to find, sound convincing and give a broad view and allow comparisons. However, there is also seen weaknesses as they concentrate on the past rather than current performance. They are slow to respond changes and do not record important aspect of the supply chains. So, financial performance measures can show that something is wrong, but it does not point it or how to correct it. (Waters 2003, p. 197; Richards 2011, p. 230)

One of the main objective for measurement is to give basic information to use in decision-making. The measurement shows how well the supply chain is achieving the targets. To get a reasonable view of the supply chain performance, there have to take a balanced view of measures. A number of measurements is not a key thing, moreover that measurements are on balance to each other. One problem that occurs often is that the different measures give different views. Moreover, they are often conflicting also. When implementing key performance scorecard for the supply chain, have to be chosen which measures are most important for the company situation. (Waters 2003, pp. 204-205)

According to Waters (2003, p. 205), a measure must relate to the objectives of the supply chain. The focus must be on significant factors and be measurable and reasonably objective. Because the idea of the performance measurement is to raise awareness about current performance, measurements have to look at current performance, not historical. Also, measurements have to be used same way in every department that it allows comparisons over time with other organizations. Measurements have to be clearly understood by everyone concerned. Measurements have to be reliable and to be difficult to manipulate to give false values. Requirements of measurement also involves that they have to be useful in other analyses.

Stevenson (2007, p. 517) stresses the importance of performance metrics. They are necessary to confirm that the supply chain is functioning as expected, or there are problems which need to raise up. There are a lot commonly known measurement which can be used, that relate to such things as late deliveries, inventory turnover, response time, quality issues and the fill rate. The fill rate is the percentage of demand filled from stock on hand.

There is also another approach to using the Supply Chain Operations Reference (SCOR) model that reflects an effort to standardize measurement of supply chain performance. Successful supply chain management requires integration of all aspects of the supply chain. Integration requires cooperation among the supply chain partners and also requires partners to agree on common goals. Cooperation to reach goals requires trust and a willingness to cooperate to achieve the common goals, this means that information exchange must be two-way: which including sharing data about forecasts, sales volumes, and inventory figures. Supply Chain Operations Reference model metrics are illustrated on Table 3. (Stevenson 2007, pp. 517-518)

Table 3 Supply Chain Operations Reference model metrics (*Stevenson 2007, p. 518*)

Perspective	**Metrics**
Reliability	On-time delivery Order fulfillment lead time Fill rate (percentage of demand met from stock) Perfect order fulfillment
Flexibility	Supply chain response time Upside production flexibility
Expenses	Supply chain management cost Warranty cost as a percentage of revenue Value added per employee
Assets / utilization	Total inventory days of supply Cash-to-cash cycle time Net asset turns

Key performance indicators make possible to summarize a large amount of complex data into understandable and meaningful values and information. Creating and using KPIs is not entirely straightforward. In particular, data collection includes problems, such key figure inflation and control issues, lack of consistency, and key figure errors. It is not reasonable to create too many indicators; whose significance is ultimately too low compared with the effort involved or other key performance indicator is covering it already. Inconsistency indicators can result in serious errors in decision-making. Thus, it is reasonable defines key indicators carefully for assuring comparability over time and across organizations. (Hoppe 2006, p. 445)

2.7.1 Service level

Service level is the performance target specified by management. It defines inventory performance goals. The definition of service level varies case by case, but usually, it is related to the ability to satisfy a customer's delivery date. Service level can be defined as the probability that demand is met directly from stock. For instance, a service level of 95 percent implies a probability of 95 percent that demand will not exceed the supply during the lead time but accepts that 5 percent of orders cannot be met from stock. (Bowersox et al. 2002, p. 286; Stevenson 2007, p. 565; Simchi-Levi et al. 2008, p. 380; Waters 2003, p. 268)

According to Richards (2011, p. 232), the best measures are those that are aligned to and governed by customer expectations. On the other hand, they also need to be aligned to company's resources. Thus there is a need to find balance the level of customer service with the cost of providing the service. Figure 16 illustrates a relationship between the ability to achieve a certain level of service and supply chain cost and performance. The cost of increasing service level from 95 to 100 percent is far greater than between 70 and 80 percent.

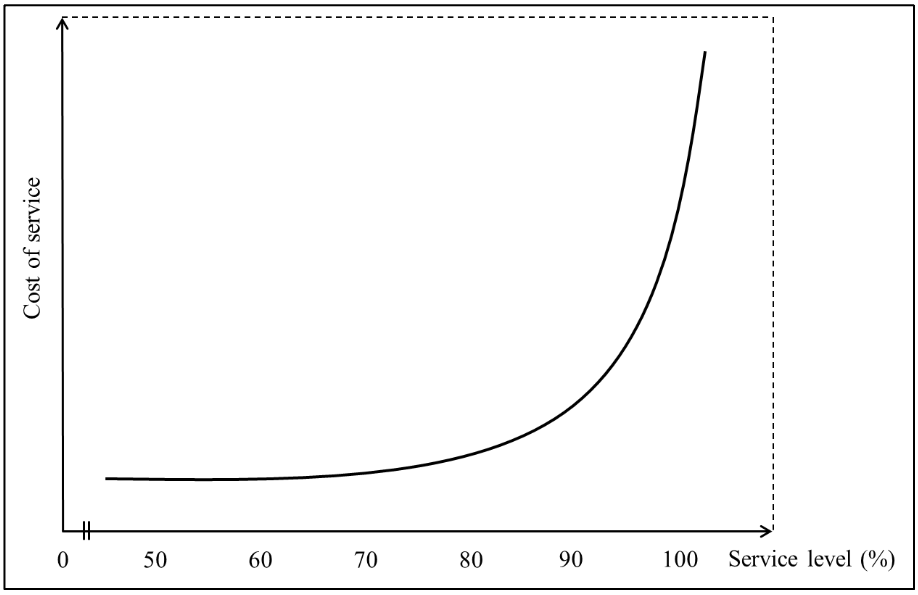

Figure 16 Connection between service cost and service level (*Richards 2011, p. 233*)

Service level is often measured regarding an order cycle time, case fill rate, line fill rate, order fill rate or a combination of these. Commonly used measures are order fill rate and order line fill rate. (Bowersox et al. 2002, p. 286) These service levels are calculated as follows:

$$Order\ fill\ rate = \frac{Number\ of\ orders\ delivered\ completely}{Total\ number\ of\ orders} * 100\% \quad (10)$$

and

$$Order\ line\ fill\ rate = \frac{Number\ of\ order\ lines\ delivered\ completely}{Total\ number\ of\ order\ lines} * 100\% \quad (11)$$

2.7.2 Inventory efficiency

Inventory management can be evaluated with various performance measures, often measures related to the rate of stock turnover or utilization of space. One of the basics and commonly used measure is the value of stock held. Stock value is seldom stable – it varies over time – normally is used average or typical values. Average inventory value is valuable to track value over time and looks for trends. If the value is rising, it might be a cause for concern. Average total inventory value is got summing for all products average number of units held multiply inventory cost value. (Waters 2003, p. 203) Average total inventory value is calculated as following:

$$Average\ total\ inventory\ value = \sum (Average\ number\ of\ units\ held\ \times unit\ value) \quad (12)$$

According to Bowersox et al. (2002, p. 560) and Stevenson (2007, p. 544) inventory turnover rate is the most common performance measure of inventory management, which is the ratio of annual cost of goods sold to average inventory investment. There are used many other variations to calculating turnover of inventory also. It is important to use same calculation when comparing turnover rates. Bowersox et al. (2002, p. 560) define a formula for inventory turnover as:

$$Inventory\ turnover = \frac{Usage\ or\ sales\ during\ a\ time\ period\ at\ cost\ value}{Average\ inventory\ value\ during\ the\ time\ period\ at\ cost\ value} \quad (13)$$

Average inventory can vary significantly during the period thus it is important to determine average inventory value using as many data points as possible. Using only a few points might mislead the management of inventory. (Bowersox et al. 2002, p. 560) Inventory turnover can also be described how many times inventory rotates during a year period. Turnover rate can be calculated by total inventory days of supply. It shows how many days a current stock has left average demand until stock is depleted. (Sakki 2009, p. 77) Total inventory days of supply (TIDS) can be calculated two ways:

$$Total\ inventory\ days\ of\ supply\ (TIDS) = \frac{Average\ inventory\ value}{Usage\ or\ sales\ at\ cost\ value} * 365 \quad (14)$$

Sakki (2009, p. 77) recommends using a rotation of profit to measure the efficiency of inventory. It is a very usable to compare profitability between items and item categories. It is a simplified return on investment for inventory items, which combines a profitability and an efficient of logistics. The rotation of profit is calculated as:

$$Rotation\ of\ profit = gross\ profit\ \% * inventory\ turnover \tag{15}$$

2.8 Spare parts classification and analysis

Spare parts management is widely researched over the past decades. Especially in the field of stocking strategies is done many researches and many models are developed to answering basic questions: What to stock? Where to stock? How much to stock? Spare parts have a variable character and them handling is many times difficult. Items classification is observed necessary when finding a solution for matching appropriate stocking policies to different classes of items. (Molenaers 2012, p. 570)

For many asset-intensive industrial sectors, spare parts classification into relevant categories is a crucial task in order to control the wide and highly varied assortment of spare parts. Using classification, targets can be set and use different forecasting methods and make different stocking decisions for different classes. The classification enables managers to focus on the most important items and facilitates the decision-making process. The importance of spare parts can differ from perspective. Classification criteria differ from a maintenance perspective to inventory management perspective quite a lot. From maintenance perspective parts unavailability would result in severe consequences, whereas inventory management perspective valuable classification criteria can be like holding cost and demand pattern when defining appropriate stocking policies for the different classes. (Molenaers et al. 2012, p. 570; Syntetos et al. 2009, pp. 292-293)

In big companies, spare parts are usually highly varied because of differing costs, service requirements and demand patterns. Thus, the classification of these spare parts varies widely. It is very common that companies classify spare parts, assigning higher service-level targets to some segment than the others. In industrial field spare parts are classified according to their criticality for the machine’s functioning. Criticality classification is a complex to evaluate, the criticality determining has seen problematic because of many aspects of criticality. The criticality can reflect how the potential unavailability affects the safety of the people and environment, the cost of downtime, the quality of the processes, etc. (Syntetos et al. 2009, p. 294)

2.8.1 ABC analysis

Waters (2003, p. 274) writes that even the simplest and most highly automated inventory control system needs some effort to make it run smoothly. For some items, especially cheap ones, this effort is not worthwhile. Very few organizations include, for example, routine stationery or nuts and bolts in their stock control system. At the other end of the scale are very expensive items that need special care above the routine calculations. Aircraft engines, for example, are very expensive, and airlines have to control their stocks of spare engines very carefully.

ABC inventory classification systems are widely used by business firms to streamline the organization and management of inventories consisting of very large numbers of distinct items, referred to as stock-keeping units (SKUs) (Teunter, Babai & Syntetos 2010, p. 343). According to Ernst and Cohen (1990, pp. 574-576), the most important reason for applying an ABC classification of different SKUs is too large to implement SKU-specific inventory control methods. According to Ng (2007, p. 344) in an organization even with moderate size, there may be thousands of inventory stock keeping units. To have an efficient control of this huge amount of inventory items, the traditional approach is to classify the inventory into different groups. Different inventory control policies can then applied to different groups.

ABC analysis put items into categories that show the amount of effort worth spending on inventory control. ABC analysis is a well-known and practical classification based on the Pareto "80/20" –principle, which suggests that 20% of inventory items need 80% of the attention, while the remaining 80% of items need only 20% of the attention. For example group "A" inventory items are those making 70% of company's business (annual euro usage) but only taking up 20% of the inventory. That means that they are critical to the functioning of the company. Group B inventory items are those representing about 20% of company's business and taking about 30% of inventory. Group C items are those representing only 10%

of company business but taking up about 60% of inventory. Classification methods based on cumulative percentage of use by value, it is illustrated in Figure 17. (Waters 2003, p. 274; Ng 2007, 344)

The ABC–approach categorizes items to:

- A items as expensive and needing special care
- B items as ordinary ones needing standard care
- C items as cheap and needing little care. (Waters 2003, p. 274)

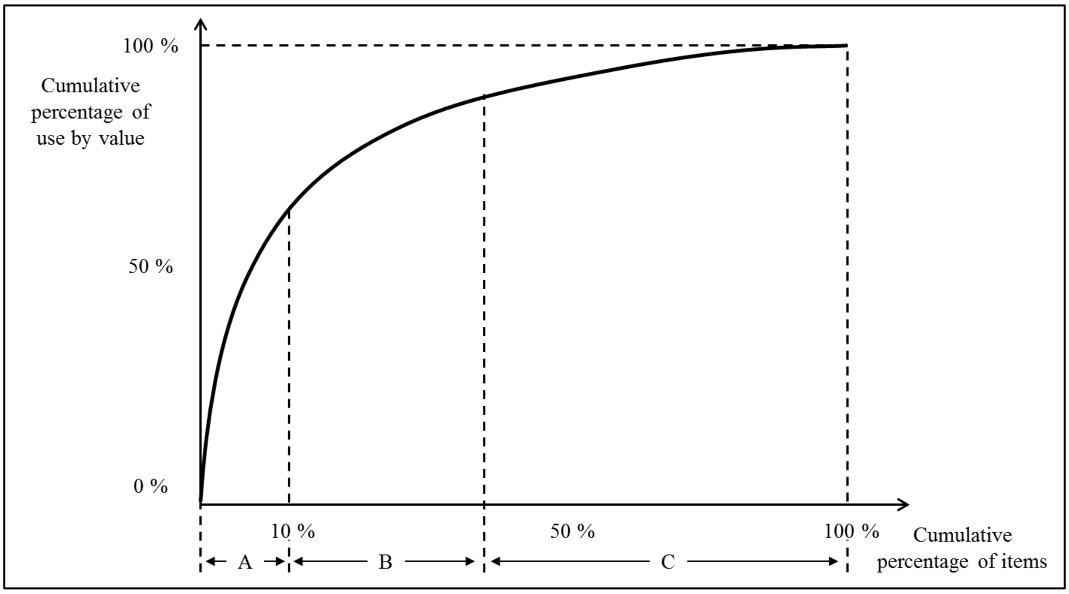

Figure 17 Typical results for an ABC analysis (A*dapted from Waters 2003, p. 274*)

According to Waters (2003, p. 274), an ABC analysis starts by calculating the total annual use of each item by value. Usually, a few expensive items account for a lot of use, while many cheap ones account for little use. If the items are listed in order of decreasing annual consumption by value, A items are at the top of the list, B items are in the middle, and C items are at the bottom. Typically might findings are as Table 4 shows.

Table 4 Typical results of plotting the cumulative percentage of annual use against the cumulative percentage of items (*Adapted from Waters 2003, p. 275*)

Category	% of use by value	Cumulative % of use by value	% of items	Cumulative % of items
A	70	70	10	10
B	20	90	30	40
C	10	100	60	100

Though the ABC-classification is very simple to understand and present, it is still very rough classification method. Many times should go into further detail after classification and maybe extend the separation to four or more classes. This is not always necessary, but many times it is advisable for a further subdivision each class because classes typically contain particularly large data quantities. In additional, it is important to keep mention to the quality of data, if data is not consistent, the ABC analysis can be very confusing. (Hoppe 2006, pp. 54-55)

2.8.2 Multi-criteria classification methods

A single criterion ABC classification method is able to give expression to it, for example, how important is classified product relation to the annual usage. Other significantly factors, such as the product delivery time or availability of the product, are entirely outside of this classification. A number of authors have considered the use of multiple criteria, such as the certainty of supply, the rate of obsolescence, the lead time, costs of review and replenishment, design and manufacturing process technology, and substitutability. (Happonen 2011, p. 4; Teunter et al. 2010, pp. 344-345)

According to Ultsch (2002, pp. 2-3) items classification by ABC analysis, items segmentation between different classes, is formed as in A class includes a few items, in B class some or some extent items and the following classes have a large amount of items. The ABC classification recognizes pretty well the top items as well as the bottom items, but the method is criticized because it does not bring meaningful results of middle-class items for controlling these items. The B class includes a significant quantity of items which economic value is major relative to the company’s annual result or the value of inventory and the annual demand is more than negligible. It is easy to choose controlling methods, for example, outsource managing of class C items because these items annual usage is very low but need a lot of resources to control them. On the other hand, it is important to optimize and follow up very closely A class items. A class includes high volume items by annual usage but only a few items include to class A. B class items are problematic, there are lot of items which have high demand volume but also items that are close C class items. Because B class includes very different items, there is not clear and individual management policy for B class items. (Happonen 2011, pp. 4-5)

Traditional and well-known ABC analysis is based only one measurement such as annual monetary usage. The analysis is very simple to understand and easy to use. The academic literature notices that it is important that ABC classification is not the only way to classify items. It has been recognized that other criteria, such as inventory cost, part criticality, lead time, commonality, obsolescence, substitutability, the number of request per year, scarcity, durability, reparability, order size requirement, stock ability, demand distribution and stockout penalty, are also important in inventory classification. Multi-criteria classification tools have been developed during two decades. Various multi-criteria methodologies have been considered, including weighted linear programming, analytic hierarchy process (AHP), and operations-related groups (ORG). An alternative for using multi-criteria methodologies is to use multiple way classifications, e.g., a two-way classification by purchase cost and demand volume. (Happonen 2011, p. 4; Ng 2007, p. 345; Teunter et al. 2010, pp. 344-345)

2.8.3 Classification by demand pattern

One possible and usable supplementary classification method is XYZ-analysis. It is a classic secondary analysis which is basically a modification from ABC analysis. These classifications are done in a similar way but in XYZ-analysis the item classification criterion is the consumption pattern of each item. The classification criterion can be for example the number of sales transactions or pick-ups from stock over a predetermined time period. Items are then assigned to different classes depending on how regularly they are sold. Logistic costs are usually correlated to the number of transactions (pick-ups or sales transactions) thus XYZ classification provides valuable information about items from logistics point of view. (Sakki 1999, pp. 105-106; Hoppe 2006, p. 53)

Items in different XYZ-classes have different characteristics. X-items are characterized by a constant and non-changing usage over time. The demand fluctuates relatively slightly around a constant level which means that in principle, the future demand can be forecast rather well compared to other classes. However, it has been noticed even the forecast for X-items can be unsuccessful. Detection of fluctuations straightaway is important that respond can be quickly and appropriately. The second group is Y-items which have neither constant nor sporadic usage pattern. Therefore, it is more difficult to obtain accurate forecasts for these items. Nevertheless, it is possible to observe trends, such as momentary increases and decreases or seasonal fluctuations in the usage. The third group, Z-items, is the most difficult class regarding forecasting because these items are not used regularly. The usage can fluctuate significantly or occur sporadically, also often observe periods with no consumption at all. It can be useful to subdivide the Z-segment into Z1- and Z2-segments, the latter being used even less regularly than the former. (Hoppe 2006, p. 60)

Hoppe (2006, p. 87) describes analyzing method where is the combination of ABC and XYZ analyses. It represents the third step in a detailed inventory analysis after individual ABC and XYZ analysis. Combining these two methods to one ABC-XYZ matrix enables to implement a specific inventory optimization process for each value. Previous studies have shown that this process can uncover new substantial optimization potentials. Commonly there is used three classes ABC and XYZ classification, hence the ABC-XYZ matrix contains nine different classes. The ABC-XYZ matrix enables to derive actions to optimize inventories. This matrix helps to choose right inventory and purchasing policy for each class. AX items have a high potential for rationalization and optimization. Conversely, CZ items only show a low economization potential. This means that CZ items should be planned automatically by systems, and use coordinators valuable time for AX and so on classes. Thus, the optimization potential is higher for A and B items, and the control overhead is higher for Y and Z items. The optimization potential and actions to optimize inventories is defined in Figure 18. It is good to mention that fluctuation increases when going from AX class to CZ.

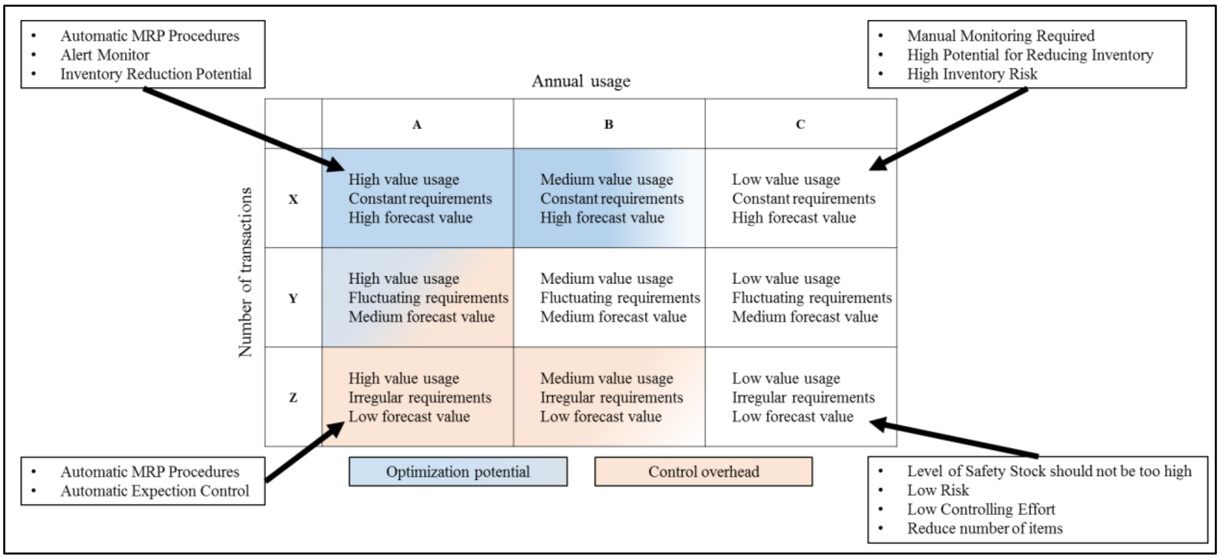

Figure 18 Inventory optimization actions and optimization potentials from the ABC-XYZ matrix (*Adapted from Hoppe 2006, p. 88*)

The planning process for AX items should be automated but also need good transparency and information on variances and exceptional situations. This kind of classification help to focus and managing on the right items. For example, the focus could put on AZ items and plan them manually because due to their fluctuating consumption they cannot be automated planned. (Hoppe 2006, p. 89)

2.8.4 Qualitative item criticality classification

The criticality of an item is probably the first feature that is pronounced by the spare part logistics practitioners, while enquired about specific item characteristics. The criticality of a part is related to the consequences caused by the failure of a part of the process in case a replacement is not readily available, and hence it could be called as process criticality. In additional, the other perspective to approach item criticality is items' control criticality. (Huiskonen 2001, p. 129)

One practical approach is to relate the criticality to the time in which the failure has to be corrected; this approach is made from a customer point of view. Huiskonen (2001, p. 129) describes three degrees of process criticality on this basis:

1. The failure has to be corrected, and the spares should be supplied immediately

2. The failure can be tolerated with temporary arrangements for a short period, during which the spare can be supplied
3. The failure is not critical for the process and can be corrected and spares can be supplied after a longer period.

Molenaers et al. (2012, p. 573) have studied criticality criterions widely. The main thing of the multi-criteria classification process is to identification relevant criteria which impact item criticality. They have presented six attributes of criticality, which help to categorize items to criticality classes. The list of criticality criteria is illustrated on Table 5.

Table 5 Process and control criticality criterions (*Molenaers et al. 2012, p. 573*)

Criticality criteria	**Description**
Equipment criticality	This criterion refers to the criticality class of equipment. Classification to classes based on a risk matrix where are evaluating class by the frequency of a failure of the equipment and the possible consequences of the failure.
Probability of item failure	The likelihood of failure or breakdown of the spare part.
Replenishment time	The total time from ordering to receiving, that it is available.
Number of potential suppliers	Numbers of suppliers who can deliver needed spare part.
Availability of technical specifications	Availability of the technical specifications.
Maintenance type	The type of maintenance performed on the equipment, corrective or preventive maintenance.

Qualitative classification methods as VED analysis, try to assess which spare parts are important to keep in stock based on the specific usages of spares and factors influencing management. The VED analysis divides spare parts into criticality classes “vital”, “essential” and “desirable”. The VED analysis based on consultation with experts and structuring the VED analysis may be a difficult task, as its accomplishment may suffer from the subjective judgment of users. (Bacchetti & Saccani 2012, p. 723; Stoll et al. 2015, pp. 226-227)

However, should be remembered that even in this case it is only one criterion analysis, which does not account for how valuable “vital” class of part can be, how much of the storage costs and cannot how good its availability is from supplier or suppliers. Research has found that well-structured spare part classifications do not consist solely qualitative or quantitative methods, but rather are their combinations. VED analysis is currently used more as one of the multi-criteria analysis methods. (Roda et al. 2014, p. 533) Molenaers et al. (2012, p. 576) are combined AHP- and VED-analysis order to achieve issues affecting the classification taken diversely but easy way into consideration (see Figure 19).

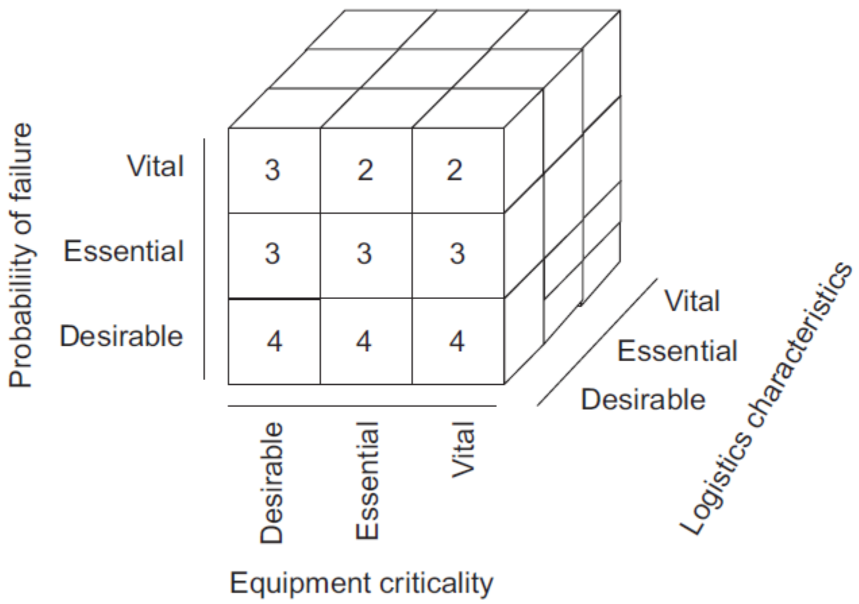

Figure 19 Combination of AHP and VED-analysis (*Molenaers 2012, p. 575*).

Stoll et al. (2015, p. 228) are combined VED analysis to ABC-XYZ classification matrix. There ABC classification is based on demand value, VED criticality classification on the criticality of machine process and XYZ visualize the predictability of consumption. With this three-dimensional model can describes inventory policy. Commonly, high-value items should not keep on every stock, especially on local small sites but if demand is uncertain evaluating should do for each item. On the other hand if the item is critical it should stock in every service site. Easily forecasting items should not be stocked, but order just before need. This model is illustrated in Figure 20.

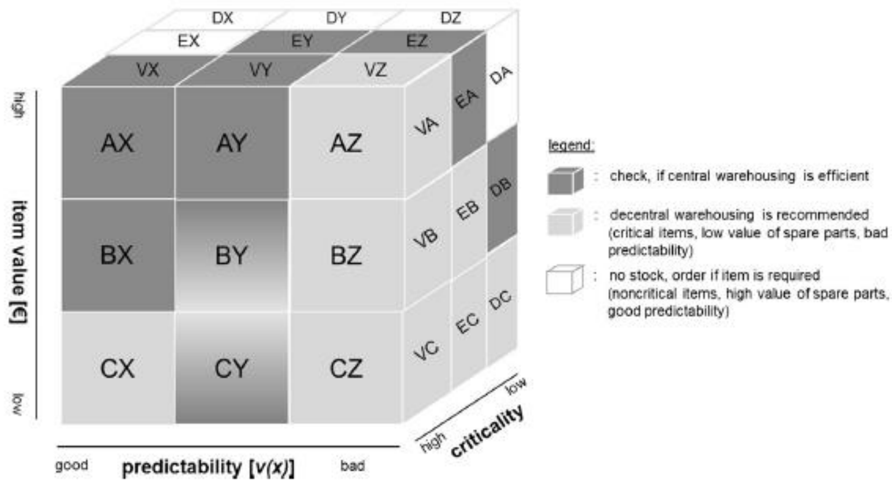

Figure 20 Three-dimensional evaluating model for stock decision making (Stoll et al. 2015, p. 228)

Stoll et al. (2015, p. 228) are used this model for making stocking decisions in a multi-echelon inventory system. For example, V-parts describe critical spare parts and require a high service level. Thus decentralized stocking at every service center is suitable for these items. Z-parts describe a poor predictability and irregular failure performance, then these parts should be stocked on site also. Also, C-parts should stock decentralized because their value is not so high that is would be sense to centralized. Also, the administrative effort will be too high that centralizing is not reasonable. Summarized, this example it that C-Z-V-parts are not suitable for centralized warehousing.

2.9 Spare parts demand forecasting

Spare part forecasting and methods are researched and tested very much in recent years. Before the deeper familiarization with the subject, it is necessary to note the following basic rules about spare parts forecasting; the forecast is always wrong, what a longer forecast horizon, the worse the forecast and aggregated forecasts are more accurate. However, forecasting tools should not underestimate because it is an important and critical tool in the management toolbox. (Simchi-Levi et al. 2008, pp. 56-57)

According to Manzini et al. (2010, p. 411), the goal of an efficient spare parts management system is to minimize the total cost. Such is mentioned this is tricky, a trade-off between storage costs and production downtime costs needs to be found. The determination of the optimal level of spare parts requires two analyses: the forecasting of future demand and its consequent optimal management. There are several different approaches to determine the future requirement of spare parts. These are the experience of maintenance personnel, which is a unique source of information, and some suppliers develop lists of suggested spare parts for local stock what is based distribution center real demand, work experience or developed tests. Third, statistical forecasting models elaborate the consumption of spare parts registered in the past and estimate future demand.

There are many different forecasting tools and methods. Methods can be divided into four general categories: judgmental, market research, time-series and causal methods (Georgoff et al. 1986, pp. 1-9). Judgment methods strive to assemble the opinions of a variety of experts in a systematic way. For example, by a combination of salespersons' estimates, using a panel of experts approaching or the Delphi method can be a very systematic way to get information about spare parts what are needed in the market area. For new product market testing and surveys, there is a potential and valuable tool for developing forecasts. This response can be extrapolated to the entire market to estimate demand for products. (Simchi-Levi et al. 2008, p. 58)

Time series methods use a variety of past data to estimate future data. These methods are widely used for intermittent demand as spare parts. According to Bacchetti & Saccani (2012, p. 722) time series demand forecasting, such as moving average or single exponential smoothing, will overestimate the mean level of intermittent demand. Despite that, these are still the most used methods in practice. Johnston & Boylan (1996) propose an adjusted exponentially weighted moving average method for forecasting intermittent demand. They show that the method performs better with intermittent demand and forecasting errors do not occur. Especially for spare parts, it is a common that there are seasonal changes in demand or some trend. For this kind of forecasting is used methods which remove the seasonal patterns from the data and then apply the approaches listed above on these edited data. If there is trend such as regression analysis and Holt's method are more useful, they can better account trends from data. For high moving and smooth demand do not need any special forecasting methods, regular time-series demand forecasting method can perform accurately for this kind of demand. (Simchi-Levi et al. 2008, p. 59)

In recent years researchers have stated that forecasting should be done according to different demand patterns, using different forecasting methods. This is seen when demand is peaky and there is used a single forecasting method; demand will generate distortion and unnecessary high inventory levels. Kalchschmidt et al. (2003, pp. 397-411) describe a model where additional information about demand is gathered from the biggest customers, and then this demand distortion can be smoothed, and it will reduce inventory levels in the supply chain and same time keep the service level at a high level.

As mentioned, there is not exists the right and best forecasting method for every kind of demand pattern. Choosing suitable method is not so simple and easy. According to Chambers et al. (1971, p. 68), if sales estimates are sufficient, a less complex technique may be appropriate. Conversely, if detailed estimates are required, more advanced techniques may be necessary. In a spare parts aspect the past is useful and important because many times during product life cycle demand is stabling, then time-series methods make sense. Otherwise, if there is significant systemwide changes render the pass less important, methods as judgment or market research methods may be indicated. (Simchi-Levi et al. 2008, p. 59)

2.10 Summary of theoretical phase and framework for empirical phase

Based on widely reviewed academic literature the case company's problem is common and broadly researched. Global spare part inventory management is challenging to manage because of spare parts special features such as uncertainty and intermittent demand and there are usually huge amounts of items. In order to ensure a service level there have to be stocked spare parts for many machines and model series. Challenging is also to control assortment of spare parts in the global inventory system. Particularly in multi-echelon inventory system stocking decisions must be existed and created. On the other words, there should be analyzed which items should be stocked decentralized and which items can be stocked centralized. Thus global inventory system needs to be successfully managed that company can find right balance between inventory value, service level and logistics and inventory costs.

Academic literature provides many classification methods for spare parts. Classification makes possible to manage a large amount of items. ABC classification method is the most commonly known method to classify items into classes. It based on items categorizing by

Pareto’s 20/80 law where items are divided into classes based on annual usage. Second, there is XYZ classification where items are divided into classes by using transaction frequency of items. In the field of the spare parts problematic is how to plan and control items which are critical for machine or equipment functioning. In the field of spare parts well-managed criticality classification is a valuable tool to handle spare parts stocking decision.

The remarkable issue is also how successful organization can forecast the future demand for spare parts. Spare parts demand forecasting is widely studied in last years. It has seen challenging due to demand pattern of the spare parts. Spare parts demand pattern can be intermittent: peaky, sporadic or seasonal demand. Hence, features of demand pattern causes challenges for demand forecasting. Erratic demand and lack of demand forecasting poses challenges for spare parts inventory management. For this reason it has seen important target for development in many studies and companies.

Performance measurement is one of the major things when managing inventories. A significant part of performance measurement is key performance indicators, which make possible to summarize a large amount of complex data into understandable and meaningful information. KPIs provide data about the current situation, and it should be utilized when developing and managing global materials management including inventories. In additional, academic literature noted that KPIs should be balanced to each other.

In the empirical phase will do current state analysis, which is divided into two section. First there are process analyses where will be explored and investigated global spare parts inventory management processes, policies and management. The objective is to get deep knowledge of these aspects. Second, there are data analyses for inventory management performance. The latter aims to clarify current inventory management performance and get knowledge of challenges by doing data analysis for inventories. On Table 6 is listed what should be examined, how it will be examined and what the purpose of analysis.

Table 6 Framework for empirical phase

What should be examined?	How to examine?	What is the aim of the analysis?
Inventories current state from financial point of view and their effect on financial figures	Analyzing financial figures from company reports. Making scenario for different situations for the future.	Motivation for the company and organization to see need of development and adapt to change.
Structure of the case company's global inventory system	Understanding the case company's global inventory structure by interviewing people and observing operation in the subsidiaries.	Getting background for the solutions and understand current state. Becoming conscious of challenges and restrictions when can find a target for development.
Global spare part delivery process and its features	Interviewing personnel from different organizations. Modelling process.	Understanding processes and finding bottlenecks of global delivery process.
Inventory managing system and item planning	Interviewing people and exploring operation of system.	Getting deep knowledge of system hierarchy and its functioning.
Item classification and stocking decision policy	Interviewing people and exploring the information systems and assortment management.	Getting understand of currently used item classification methods and product policy. Also to get knowledge how the case company is controlling critical spare parts.
Performance management, key performance indicators, review practice and target setting for inventory management	Interviewing people and examining current performance management.	Understanding current performance management and finding pitfalls.
Spare parts replacement and superseding process	Interviewing people, exploring, and modeling spare parts superseding process.	Understanding current superseding process and getting findings.
Spare parts return policy	Interviewing people and exploring return policy of non-rotative parts.	Understading of current policy for non-rotative spare parts return.
Down-write policy and its effect to company's finance	Interviewing personnel and making data analysis of the current down-writes in the case company.	Knowledge of down-write process and financial effects.

Spare parts recommendations for new products	Investigating recommendations and the whole process.	Accurate of recommendations and how process working in the product life cycle.
Spare parts demand forecasting	Interviewing people and exploring the system and process.	Understanding of current demand forecasting efficiency and its effect to inventory management.
Inventory performance analyzes	Doing data analyzing for inventories.	Accurate data-based analysis of the current state and problems in inventory management.

The objective of current state analysis is to get findings and reasons for the main problem. Based on findings will aim to solve the research problem and develop solutions for it. The aim is also to increase the organization's understanding of the current situation and propose further studies in the subject area.

3 CURRENT SPARE PARTS INVENTORY MANAGEMENT

This section presents the current state of the case company's global spare parts inventory management. The purpose is to describe the current situation and find objectives for a development project to create a solution for the main problem. The source information of current state is collected by observation and interviewing people globally in the case company and also the author's personal experiences of a career in the case company are mentioned. Inventory data is got from the case company's ERP and material planning systems.

3.1 The progression of current state

The case company's business has grown and globalized rapidly in the last decade. Turnover has increased overall 64 percent in last five year and at the same time current assets has increased 45 percent. The capital turnover has not improved as expected, it has weakened continuously from 2014 (see Figure 21), which was 1,72 in end of the year 2016. Another finding of the need to development current assets management and especially spare part inventory management is that the case company's balance sheet has been growing faster than turnover, mainly due to high growth of spare part inventory value.

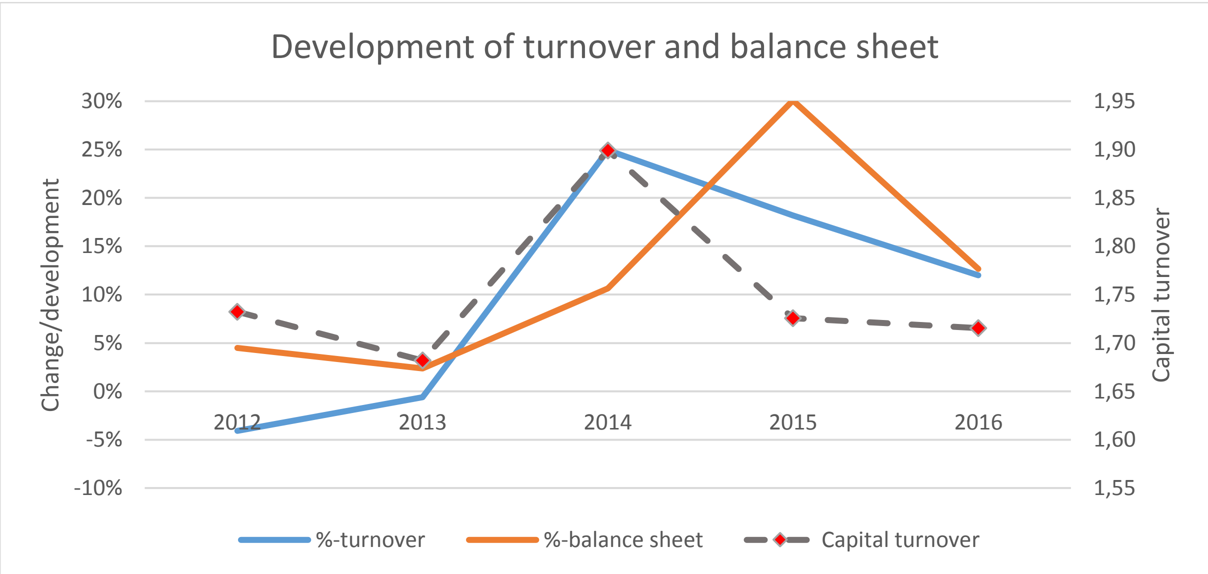

Figure 21. Company's balance sheet has grown faster than turnover from 2014

Percentage of working capital has been developing very well from the year 2012 to 2016. Working capital has remained rather reasonable mainly due to good balance of trade receivables and payables (Figure 22). Improving the current assets management the percentage of working capital could be easily still better. Another finding of that is that cash flow correlates with the current assets and raw materials stock development very strongly (see Figure 23).

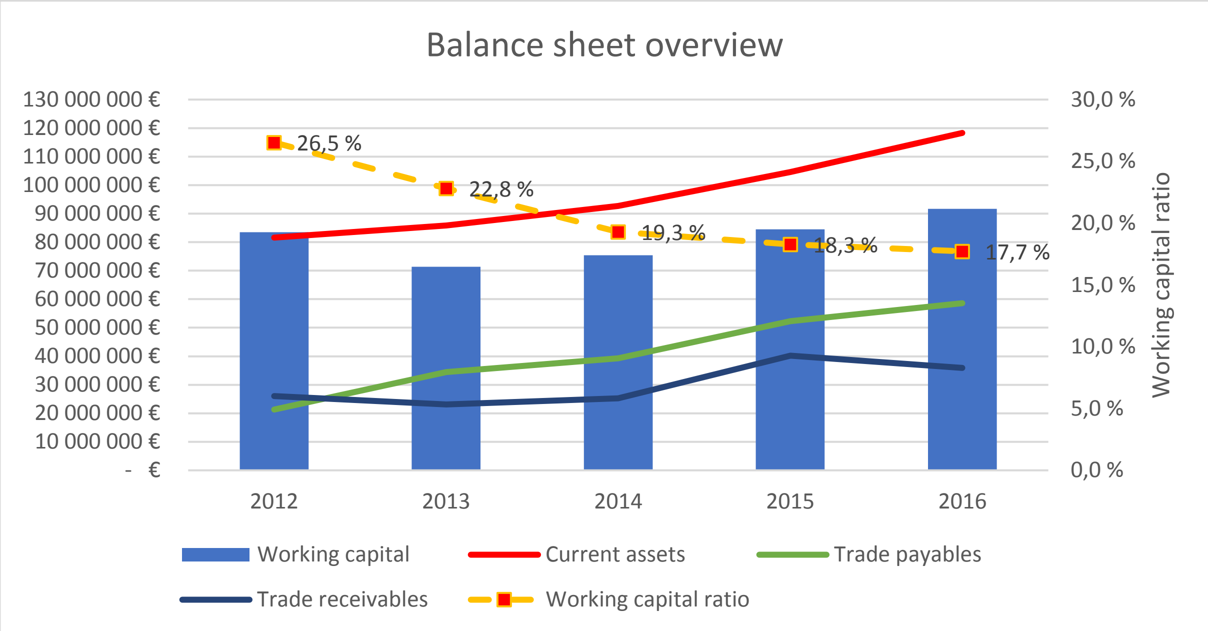

Figure 22 Working capital ratio has been developing very well from the year 2012 to 2016

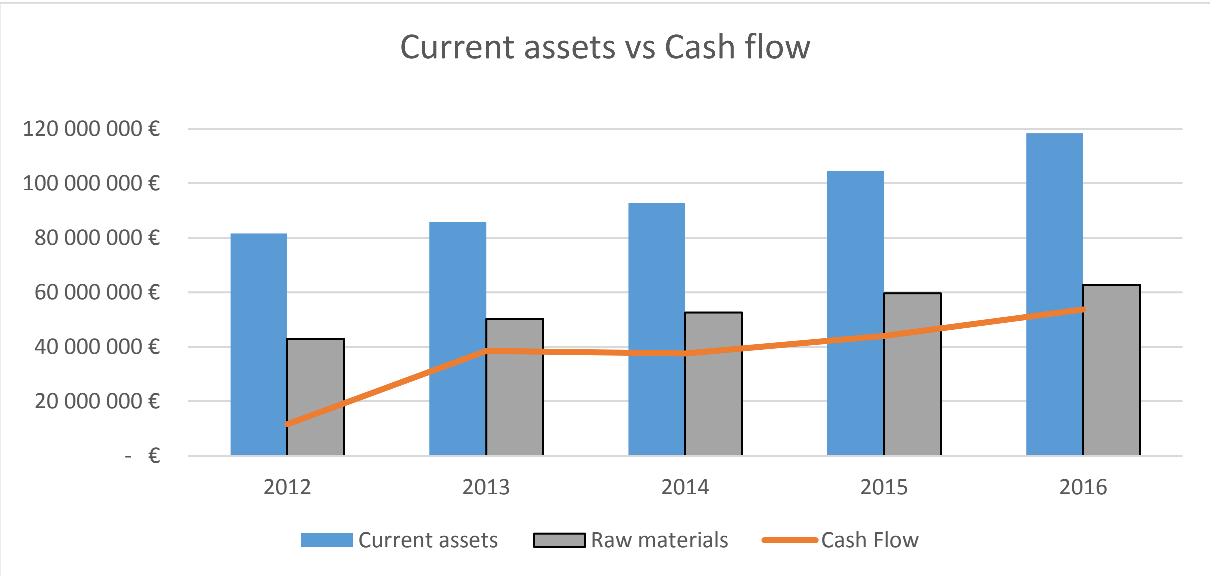

Figure 23 Development of current assets and cash flow

The spare part inventory turnover developed nicely until 2014 but after that inventory turnover slowed down at the same time of launching new machine model series (see Figure 24). The launching of model series in 2014-2015 started to grow inventory value very fast. The reason for that was a huge amount of new items but there are still need to keep spare parts for older model series in stock. In 2016 the average rotation of spare part inventories was around 265 days. In order to keep the cash flow at the good level inventory turnover should develop faster than stock values increase. In last four years the case company spare part stocks are increased approximate 10 percent but inventory turnover has developed approximate only three percent. This describes that efficiency and processes are not improved so well than would need to be.

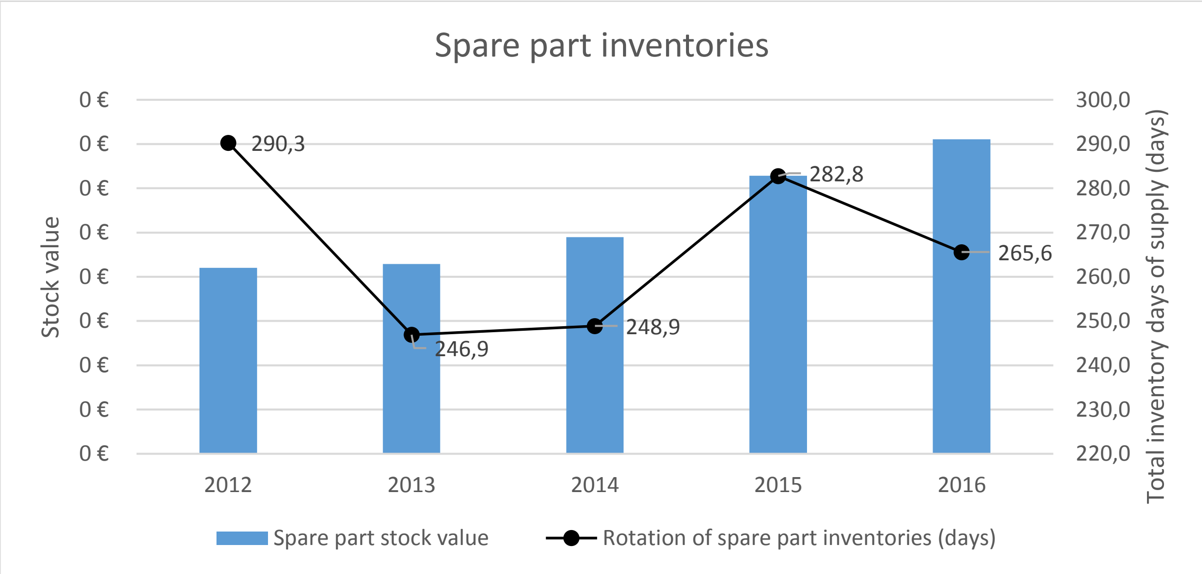

Figure 24 The case company's rotation of spare part inventories (stock values are encrypted because of confidential reasons)

The number of active machines have increased at the same time rapidly which has put pressure on the whole supply chain and aftersales. During a huge growth, the company has not been able to handle global inventory management sufficient profitable way. Policies and processes have not developed sufficiently fast, and implementation and philosophy of continuous improvement have not taken place globally. For inventory management, there has also been challenging to handle new products and model series; product assortment has grown at the same time when have to protect customers satisfaction who have old machines. It is noteworthy to mention that the machines product life cycle could be more than ten years active working on high utilization rate. Thus, the product life cycle management is also complex and need attention.

3.1.1 Optimistic and skeptical scenarios for the next four years

In order to get still better understand about current state, there is made scenario map for the next four years. The following scenarios are based on firm's current development assuming that company's growth is continuing as the past four years. The purpose of scenario mapping is to evaluate what would happen in the future. The scenario is mainly done from the financial point of view.

If company's growth would remain in existing level balance sheet would increase to 535 million euros until 2020. Hence the capital turnover would deteriorate from current 1,72 to 1,60 until 2020. Company's working capital ratio has been approximate 21 percent in last five years. Thus the working capital would be 171 million euros in 2020. The scenario is illustrated in Figure 25.

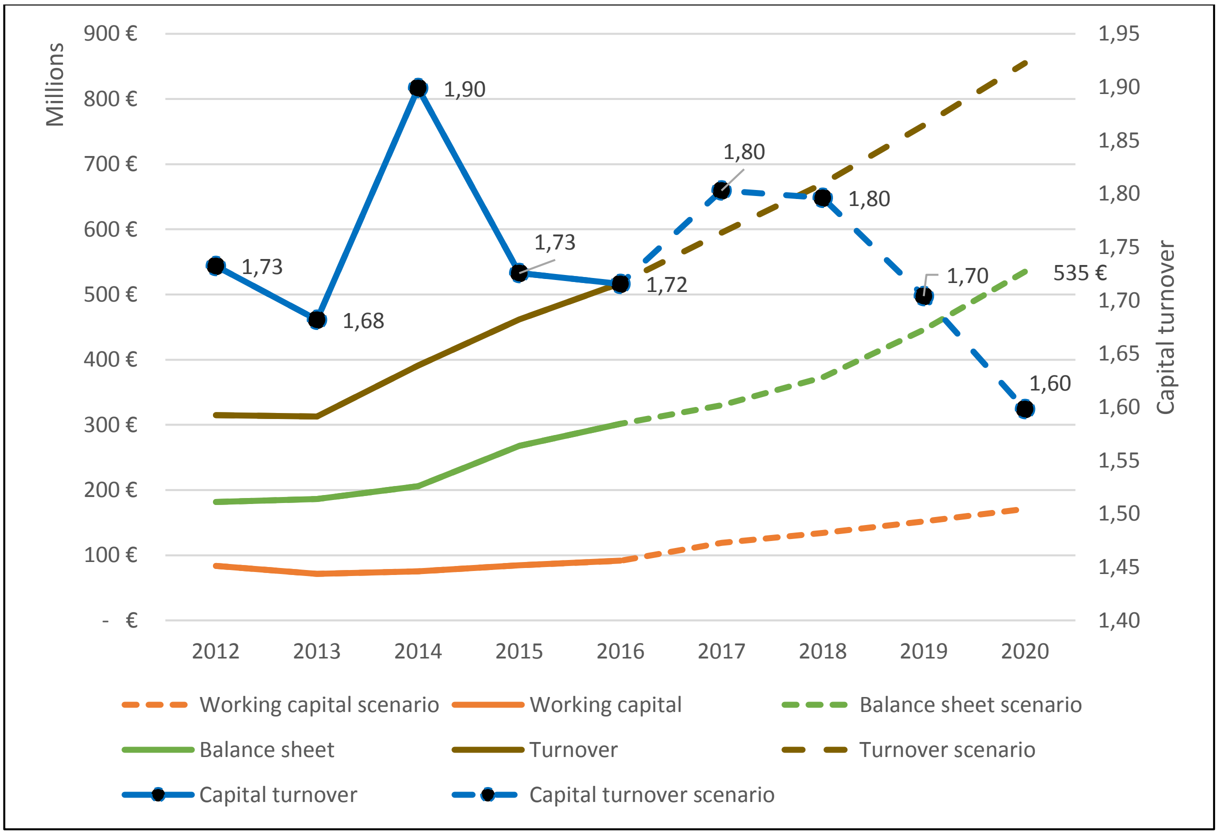

Figure 25 Optimistic scenario for turnover, working capital and balance sheet

The current assets has been approximate 120 percent of the working capital in the past. Company's current assets has been approximate 42 percent of balance sheet in last four years. Assuming that current assets value ratio will remain at same level and current assets turnover continues developing, it means that the current assets value will be 205 million euros in 2020 (see Figure 26). Based on historical data raw materials value has been approximate 60 percent of current assets value. Hence raw materials, which are basically spare parts in the global inventory network, will be 123 million euros in 2020.

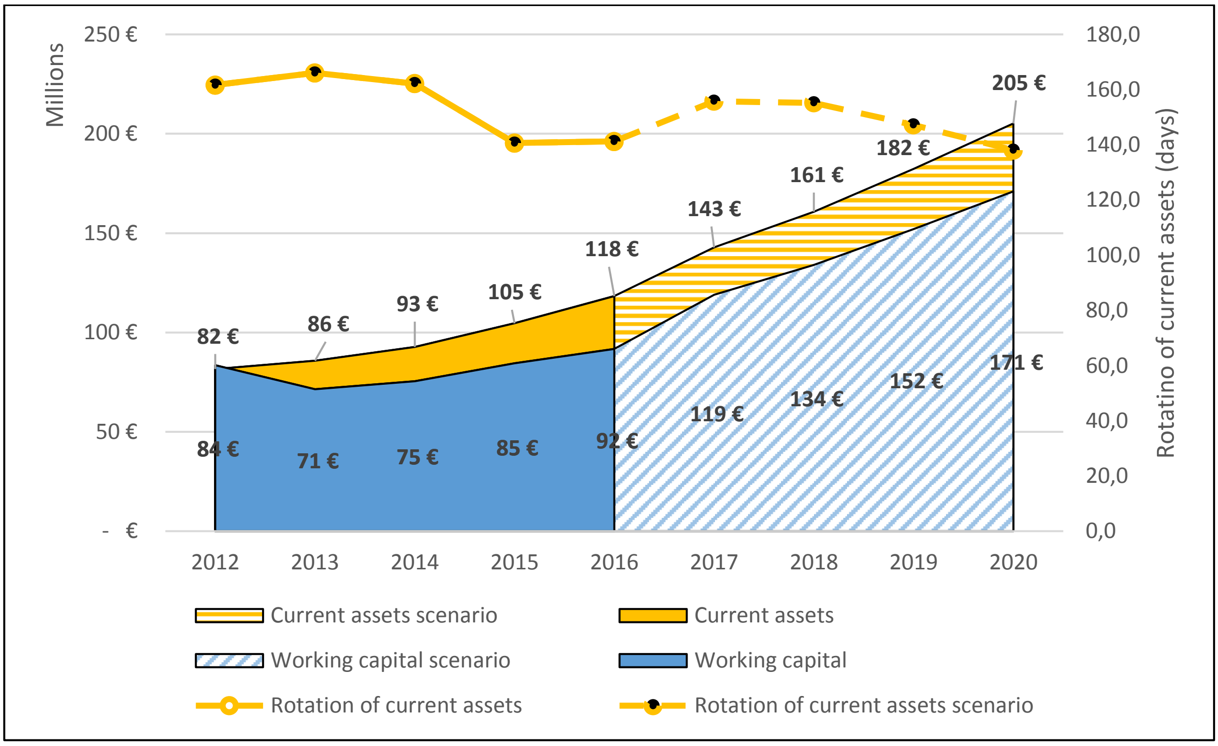

Figure 26 Development of current assets and working capital

In the case company's business area growth has been really fast variable and during many last years company has grown faster than the whole business sector overall. The sector is also associated with strong and rapid fluctuations in demand. Thus, it is reasonable to evaluate different growth scenarios and evaluate how capital turnover is corresponding to different growth scenarios. The case company has grown approximate 13,4 percent in last four years. In Figure 27 is illustrated two other scenarios for capital turnover; scenarios for 10 percent and 5 percent growth. Scenario shows how capital turnover would develop if balance sheet would be even same level than in 2016. In worst case capital turnover will decrease to 1,18. In reality, a successful company should modify its balance sheet but especially spare part inventories are not so easy to change to cash.

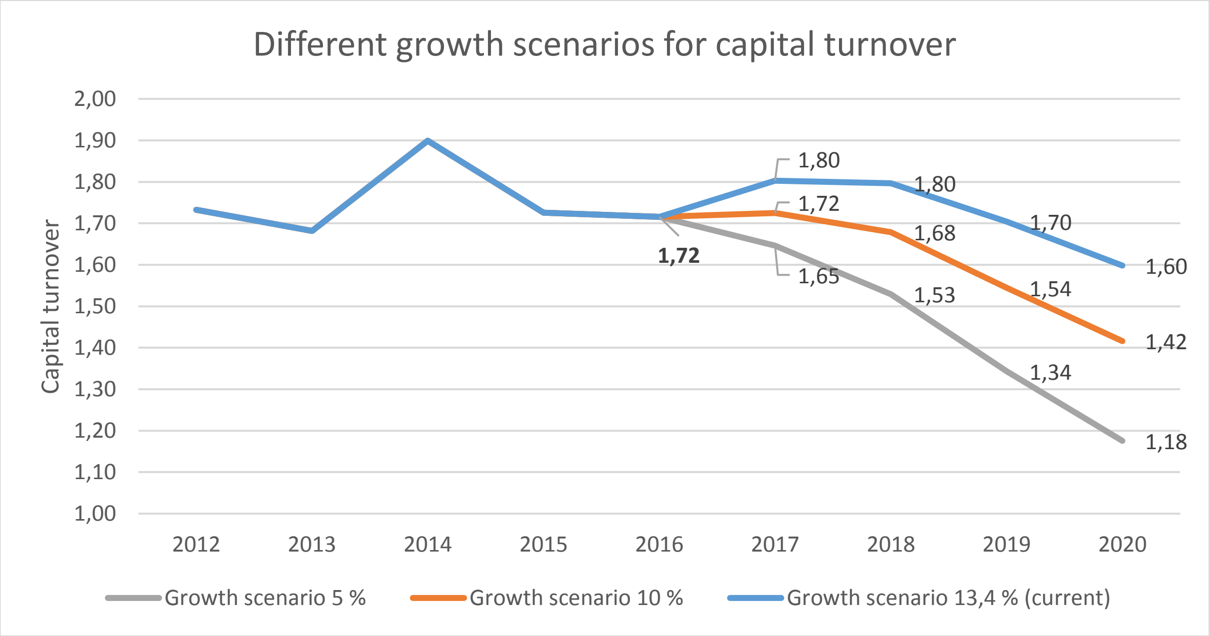

Figure 27 Growth scenarios for the next four years

3.2 Spare parts supply chain in the case company

The case company's global spare parts network is based on the multi-echelon inventory system. The case company group consists ten subsidiaries (country company) which are spread worldwide, and the service network consists more than 30 service sites and spare part warehouses. This thesis focuses on two subsidiary's inventory management including a distribution center. The reason for this scope is thesis project's limited schedule. The subsidiaries and sites for research have scoped the way that there are significantly differ geographically and business cultural of each others.

In Figure 28 is shown case company's global network and subsidiaries location. In this thesis research will scope to Sweden and the United States located subsidiaries and the distribution center that is located in Finland. The reason for this choice is due to the need to study the impact of logistical differences on global inventory management. This will give the most reliable understanding of the needs of the global network.

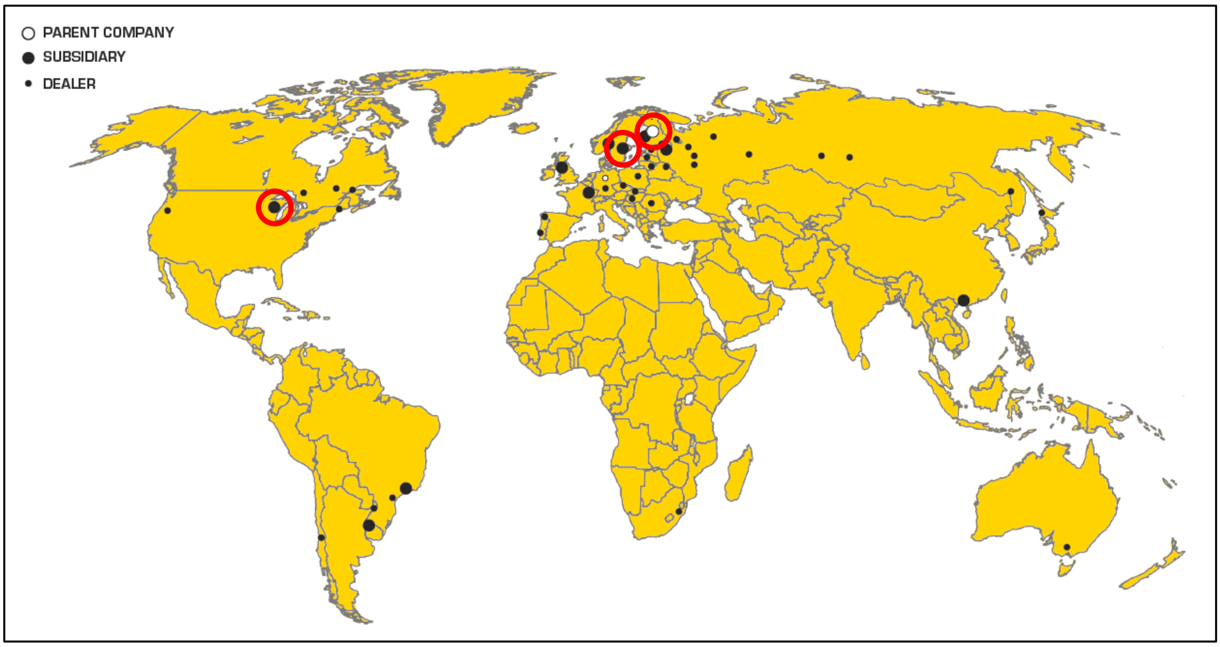

Figure 28 The case company's service network and the scope of research

In this thesis are examined with two subsidiaries, one in Sweden and one in the United States. Swedish company (AB) is located in two locations which are ASE and VAS, the latter being also the main warehouse of the region. US company (NA) sites are RHI and MII where RHI is correspondingly the main warehouse. Names of the sites have been changed due to confidential reasons.

3.2.1 Spare part delivery process

All of the case company's suppliers deliver shipments to the distribution center where global spare part distribution network is managed. Every subsidiary has an own main warehouse where spare parts are distributed to service center sites. Sometimes in the urgent cases the distribution center dispatches spare parts directly to the end customer. Such as in the literature, this material distribution model is called as a multi-echelon inventory network. Figure 29 illustrates a spare part supply chain of the case company.

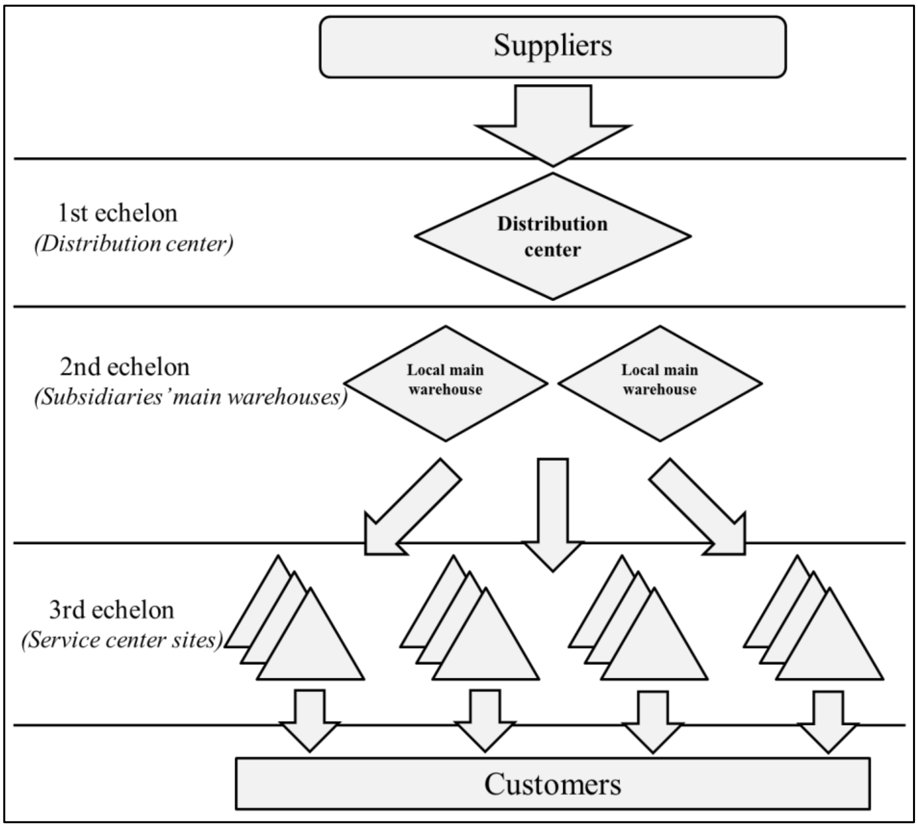

Figure 29 The case company's multi-echelon spare part inventory network

The first phase of the delivery process starts from purchasing. Purchasing department purchases all spare parts from suppliers. Supplier confirms delivery date and price via ERP system interface application or manually by email. When supplier delivers the shipment to the distribution center, the distribution center personnel receive pallets and packages. In receiving process receiver checks that every delivered line is correct and shelves items to the specific storage location. When subsidiary spare part department orders spare parts from the DC, the export spare part sales department process the order doing customer order and release it to the warehouse management system. Subject to the order type, the order goes to the picking queue. In an urgent situation, delivery time must be shortened. Then express orders are prioritized to high and they overtake other sales orders. On Table 7 is defined export spare part order types, prioritizing and frequency of delivery

Table 7 Order types in export spare parts sales

Order type	Prioritizing	Delivery frequency
Stock order	3.	~daily-weekly
Express order	2.	~daily
Machine down rush order	1.	~randomly (depends on)

When delivery lines are picked and packed for shipment on predetermined picking date, the order will be dispatched on the desired delivery date and shipped to the consignee. Normally, the export sales department is responsible every order and supplying the parts to the customer. In some cases, parts are delivered directly to end customer but typically only to customers who are in the European Union area. At the moment the delivery term is used CIP (Carriage and Insurance Paid To (*named place of destination*)) which means that consignor delivers the goods to the nominated carrier at the place of loading at the agreed time of delivery. That means the seller contracts transportation, pays the freight to the agreed destination, also insures the goods during transit, and takes care of export formalities.

When the shipment arrives at the destination, it is received to storage same way as in the distribution center. Those subsidiaries which are located out of European Union they have to declare goods in customs. Commonly, subsidiaries are using a broker who is managed import to the destination country. Every subsidiary, if they have more than one service center**,** they have the central warehouse where is managed centralized internal material orders. The whole spare part supply chain process is described more specifically in Figure 30. The process modeling is done by using the swimlane technique.

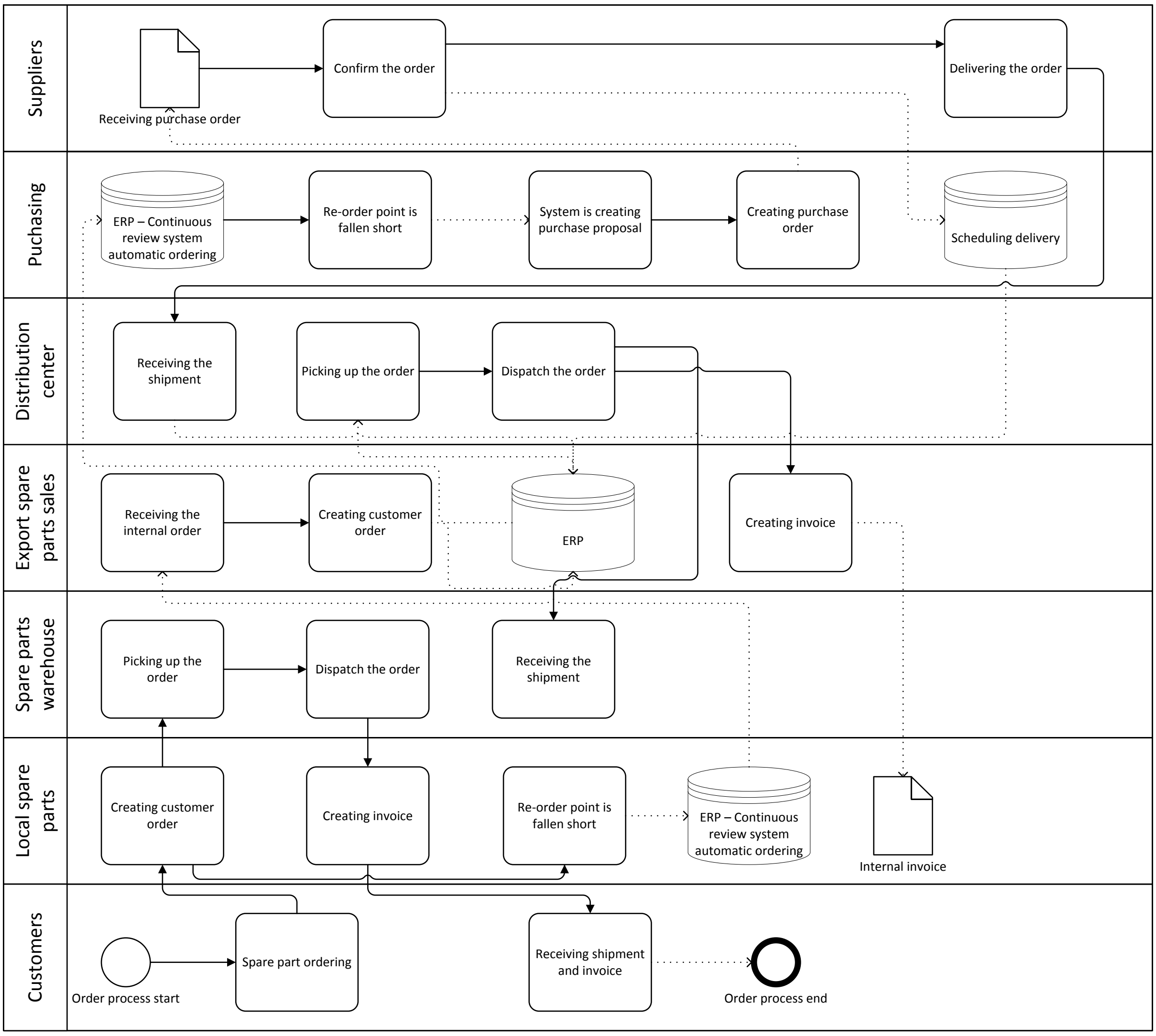

Figure 30 The case company's spare part supply chain process

The whole case company group and every site use same ERP system, which enables full transparency for all users. As literature notes that it is remarkable that transparency and cooperation between sites is seamless. In order to create an efficient supply chain, open information systems have to be improved, and collaboration within the supply chain need to be developed.

3.3 CMI – Centrally Managed Inventory system

The Company uses Centrally Managed Inventory system, CMI, which is a concept to created ensuring high service level for the customer with reasonable inventories. The main idea of the concept is to release resources and ensure more efficient spare parts supply chain. CMI makes possible automatic replenishments orders without manual order working. The responsible spare part person will only check and approve order proposals. The system takes care that needed parts are available in the right place at the right time. Inventory planning basis on a continuous review system, which is commonly known in academic literature as well.

3.3.1 Information system structure and data flow

The case company has introduced material planning software during the year 2008. The material planning system is used to manage global spare part inventories along the supply chain, from purchasing to all service sites and warehouses. Material planning system and ERP system are connected to each other, and together they form the basis of CMI concept. The data flow is transferred continuous that begins from ERP system transmit needed materials management data to the material planning system. Using this database the material planning system calculates inventory control parameters for every item and transmit data to the ERP system. Item planning and ABC categorization are done every overnight. The CMI concept architecture and data flow are illustrated in Figure 31.

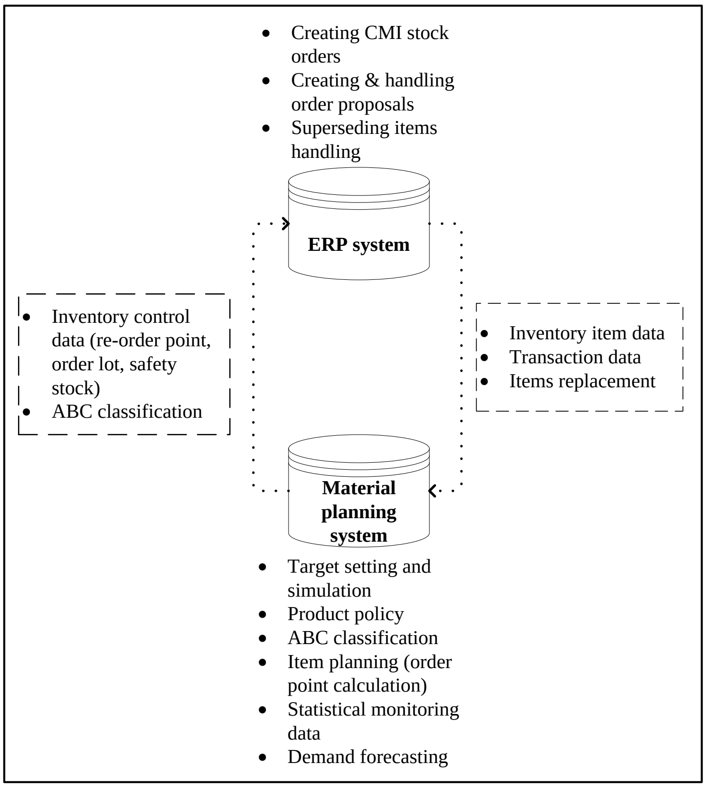

Figure 31 The CMI concept; software tasks and data flow

3.3.2 Item planning and target setting for inventories

The whole inventory management is based on targets setting where the management board of the company (each subsidiary) sets targets for spare part sales, spare part stock value and inventory turnover. The target setting is a yearly process where are set targets for inventory management in each subsidiary. The target setting will be generated to the material planning system, which calculates order point, safety stock and order quantity for stockable items.

There is CMI team in the supply chain department, which manages targets implementation to the material planning system. In the company, target based inventory management is called as a simulation. In material planning system, the simulation is made for planning and managing inventories with the set targets. In the simulation, there is set control values for stockable items for each inventory (see Figure 32). For simulation, there is needed ABC class specific targets for sales (consumption estimation), turnover rate, availability and needed safety stock. When the simulation is done, the system will calculate control parameters for automatic item planning for each item.

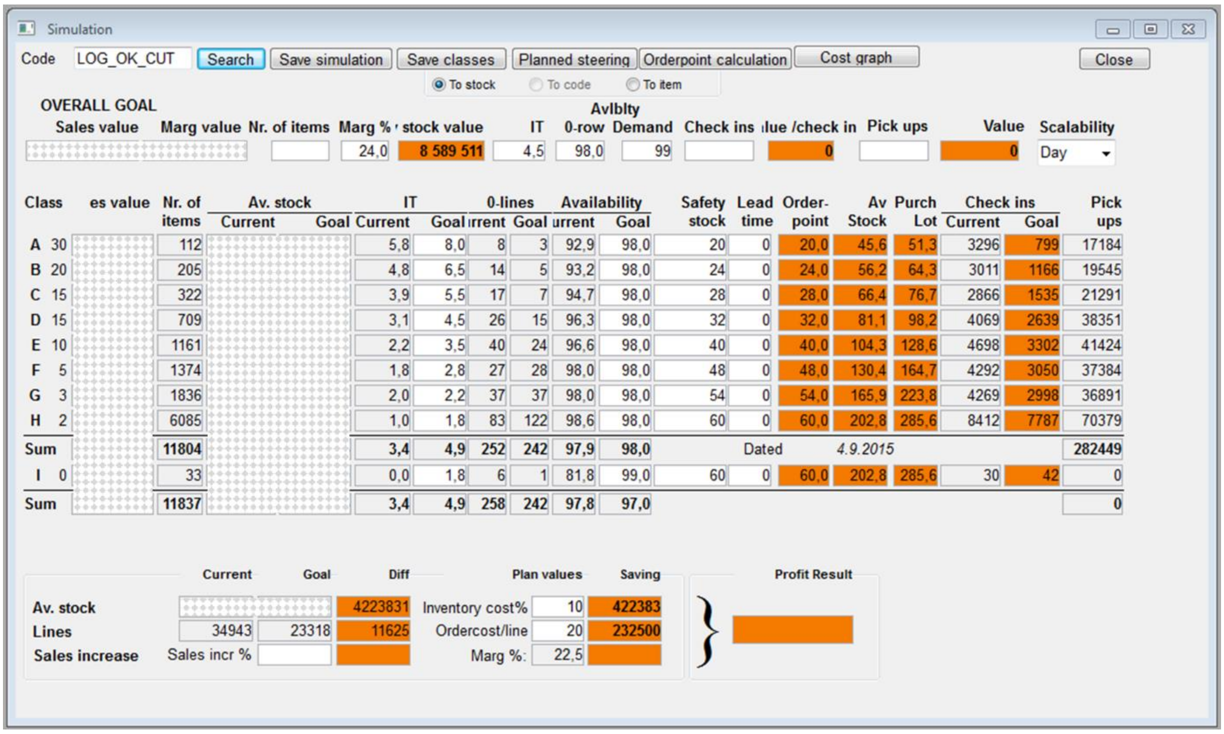

Figure 32 Target setting tool in the material planning system

CMI team reviews and re-evaluates targets normally once a year but systematical review practice is not existing. By observation there is not set even same targets to material planning system as set up in management board of the subsidiary. The management board of subsidiary set targets for the whole subsidiary and currently it is confusing who is responsible set targets for each site in the subsidiary. From the performance management point of view this is a critical issue at the moment in the case company. The whole performance management needs to be clear and consistent.

The material planning system is managing item planning automatically, the system calculates and controls safety stock, order lot size and reorder point. Safety stock depends on the lead time and a demand during lead time. The system plans and controls item planning every overnight. The system also calculates an economic order quantity (EOQ), but the system does not use it directly though it is only additional info for item planner. An academic literature recommends using EOQ if inventory and order costs are determined. Item planning can be done by manually also. There is possible to keep items in manual planning if these are wanted to keep in stock or demand will be significantly greater for the future (for example totally new items or campaign parts). Item planning tool can be seen in Figure 33.

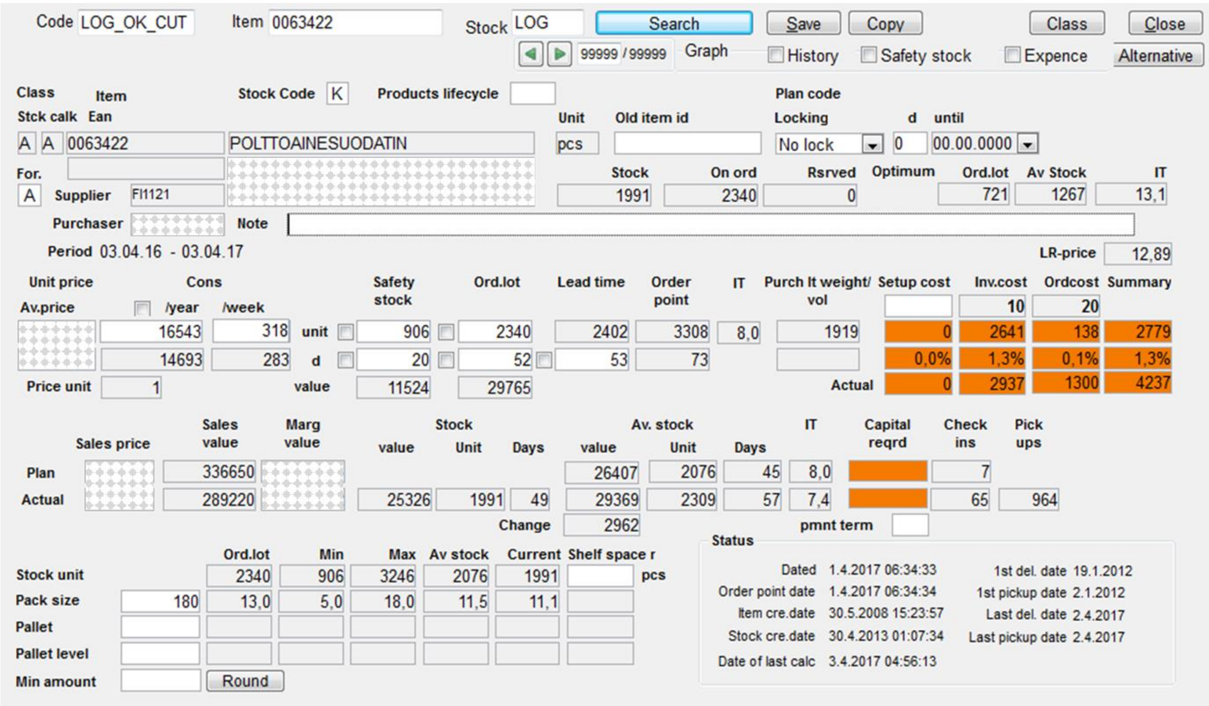

Figure 33 Item planning tool in the material planning system

In order to CMI concept works well there are several things and tasks what have to be done right way on time. General processes and transactions in ERP system must be done correct way. Material planning system calculates control parameters for each item and class based on customer orders, work orders and purchase order values. Thus they must always be up to date and used right way in systems. New items and superseded items should be planned and manually planned items up to date in order to CMI can work correct way. Product policy is a major task when are making stocking decision for items. The concept of product policy in the case company is described in section 3.4. From the management point of view, the simulation needs to be done regularly in order that inventory control is up to date with right parameters. It can be said that the simulation is the basis for target-controlled inventory management in the case company. Basic requirements for CMI properly working are illustrated in Figure 34.

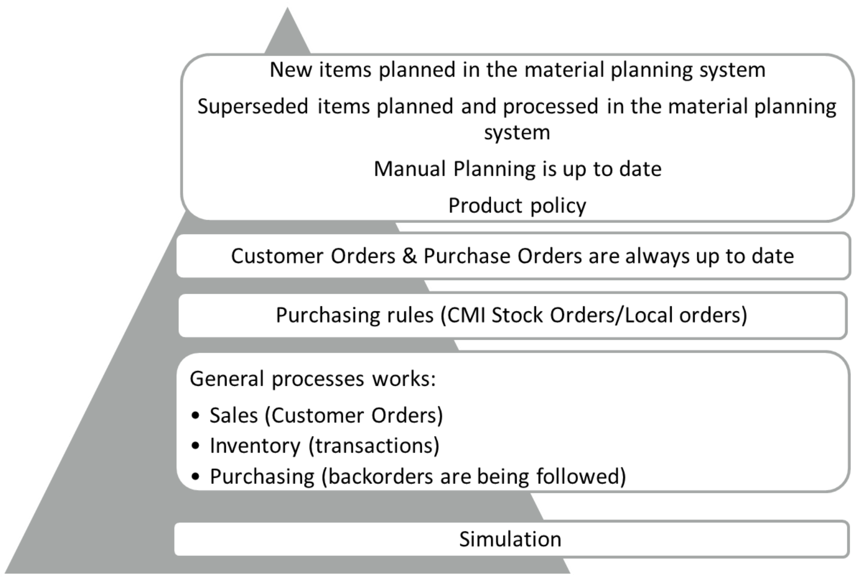

Figure 34 Basic requirements for CMI working

Summarized, there are responsibilities for the management board, CMI team and local spare part team in the current CMI concept (see Figure 35). After that information systems are (material planning system and ERP system) managing the operational work and processing either fully automatically or semi-automatically by the material coordinator.

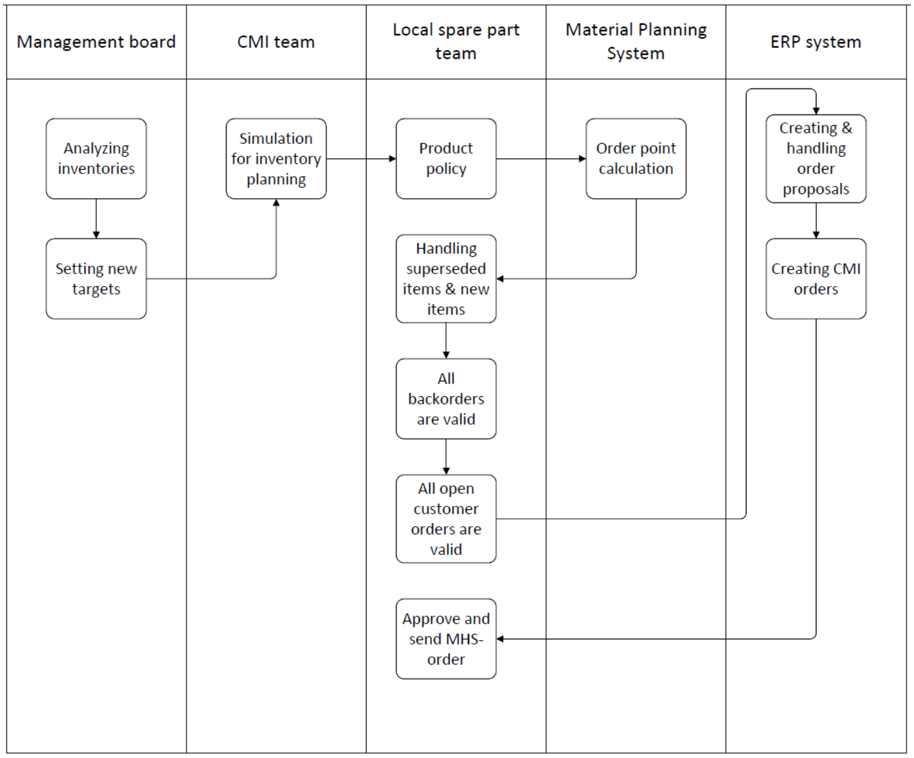

Figure 35 Responsibilities in CMI concept

3.4 Item classification and product policy

The case company has almost twenty-thousand active spare part items. To handle a huge amount of items, some classification is mandatory to be in use. The case company uses ABC classification, where warehouse specific items are divided into nine classes and categorizing is based on 12 months annual sales volume which including the profit margin. Items in A class generate 30 % of the sales volume. B class including the next 20 percent of sales volume, and so on. The classes and its dividing policy are summarized on Table 8. Other classifications are not in use at present. This classification method is a well-known in the literature albeit the academic literature recommends using the cost of goods sold (COGS) in the basis of categorization. Thus, the variable margin of items would not affect to items categorization.

Table 8 The case company's ABC classification and range of classes

ABC class	% of sales volume	Cumulative % of sales volume
A	30 %	30 %
B	20 %	50 %
C	15 %	65 %
D	15 %	80 %
E	10 %	90 %
F	5 %	95 %
G	3 %	98 %
H	2 %	100 %
I	0 %	100 %

In the case company ABC classification is run overnight. I-class including items had not any sales in last 12 months. In practice, every item begins to be in I class. For instance, when item meets demand then it is going to be higher classes, also if demand is decreasing it can go back to I class. Classes and the whole classification system are created to handle and plan efficiently items that are performing similar way. Table 9 illustrates better how difficult and challenging manual planning could be. In every site, they might have even hundreds or thousands of items in one class and totally there might be even twenty thousand active items.

Table 9 Quantity of items in ABC classes

ABC class	LOG	VAS	ASE	MII	RHI
A	135	50	32	40	53
B	256	109	51	96	141
C	408	170	74	155	244
D	912	379	147	349	540
E	1525	612	224	553	879
F	1831	701	241	589	1031
G	2586	922	309	706	1353
H	11006	2919	909	2040	4765
I	36624	52165	56442	51980	47663
Grand Total	**55 283**	**58 027**	**58 429**	**56 508**	**56 669**

The case company is managing stocking decision with a simple policy. In every week is done the product policy, where system processing automatically item transaction history. Material planning system makes proposal list of items that should change to stockable and non-stockable. Stocking decision is based on the transactions during previous 12 months, if an item has three or more pickups in last 12 months, it will change to stockable item. If pickups are less than three, it will not be stockable yet or anymore. Stocking decision is based on local professional also if local spare part personnel evaluate that they have to keep the item in the stock or not contrary to the proposal, they can do that. Conversely, if the part is rare or/and it is not reasonable to keep in stock, then the part will be ordered only for customer demand. Spare part person's experience and knowledge are primary importance and valuable in making these judgments. Also, an academic literature points out that aspect.

Current stocking policy is simple and people understand it. The case company does not have any other classification method in use, but especially for stocking decisions it would be needed. It would be possible to categorize items to help make the decision for centralized or decentralized stocking decisions. The literature observes that items criticality classification is useful when making stocking policy; to stocking centralized or decentralized near the end customer.

3.5 Current performance management and measures

As literature says, performance measurement, monitoring, and actions follow-up of progress are in the important role when managing global inventories. In the case company every subsidiary has own management board where are members of both the subsidiary and the parent company. The board will meet every second month, and they check common management things. For inventory management, basic KPIs are monitored, such as inventory value and turnover rate. In review, attention is paid mainly to significant changes and trends of inventory characteristics. After the budget the management board sets targets for each quarter. Based on thesis project interviews targets are not so clear, and improvement plans and actions are not in use. The key performance indicators are not existing on the local level of the network. Any targets or goals for performance measurement are not given for local managers either. Also, there is not exist the process-based follow-up for implemented issues. On the stage of managers, this is seen problematic. Such the academic literature points, if targets are not set, they cannot be achieved.

There is also an internal audit, which is done once a year for all subsidiaries of case company Group. The audit is called ESW (Efficient and Safe Workshop) where evaluating service centers' operations. The target of ESW is to improve customer service, recognize local strengths and development areas. The results are used for improving efficiency and safety in the service department. The goal of the audit is monitoring and improving economic results. On the field of inventory management, the ESW audit includes evaluating indicators as a spare parts availability, which describes current availability from stock. Availability is calculated by stock outs per stockable items:

$$Availability = \frac{Stock\ out\ items}{All\ stockable\ items} * 100\ \% \tag{16}$$

The stockout item has been out of stock during a review period. The service level is calculated by the stock out items that are reserved for customer order towards all stockable items during 12 months. In academic literature this is also known as the order line fill rate. This indicator describes better relative of the customer satisfaction. The indicator also describes indirectly quantity of backorders. The service level is calculated in the system as:

$$Service\ level = \frac{Ordered\ items\ delivered\ promptly\ from\ stock}{Total\ ordered\ items}\ in\ 12\ mths * 100\ \% \tag{17}$$

There are also monitored a number of stocked items, stock value and stock value per active machine fleet in the market area. Also, the annual spare part sales is compared to machines in the area. There is also monitored an inventory rotation time, total inventory days of supply. The inventory turnover rate is calculated as following:

$$Inventory\ turnover\ rate = \frac{Cost\ of\ Goods\ Sold\ (COGS)}{Average\ stock\ value} \tag{18}$$

and officially used indicator for inventory turnover is rotation of spare part inventories:

$$Rotation\ of\ spare\ parts = \frac{Average\ stock\ value\ (last\ 6\ months)}{Purchases\ cumulative\ 12\ months} * 360 \tag{19}$$

Officially used indicator has seen problematic at operational level because there are used only six calculating points, such as average inventory value of last six months (months' last day). Thus, changes in inventory management and planning are not recognized immediately to performance indicators. The inventory turnover rate describes better real inventory turnover because it is calculated from everyday values during last 12 months. Thus, there are used 360 different calculating points. In addition, ABC summary from material planning system shows daily inventory turnover rate thus it is possible to monitor for personnel. Problematic is that company does not have any performance scorecard. Another challenge is that financial department, which monitoring financial figures, takes values from financial database using previous determined total inventory days of supply. Such as literature notes, performance measurement should be clear and respond dynamically daily changes or should be possible to see the improvement immediately. Also evaluating of inventory management should be done same way everywhere in the company thus the managing and leading would be easier.

3.6 Superseding process

The case company's business is growing fast as well as technology is evolving rapidly. Thus, the case company has to do product development upgrading their products constantly, and as a result, new items designed constantly. There are also a lot of product variations and options. Due to these spare part assortment is a huge and causes problematic aspect for the inventory management.

Product changes cause a lot of item replacements. Without properly working superseding process old items do not consume and new items are coming to network causing overlapping and growing inventory values. In the service center warehouses can be stocked a both the new and the old item. This is problematic because old items do not rotate anymore and invested capital will come obsolete. In order to avoid this, the company has created a superseding process whereby managing that new items cannot be ordered before old items are consumed. However, there is observed that the process is not fully working at the moment. The current superseding process is illustrated more accurate in Figure 36.

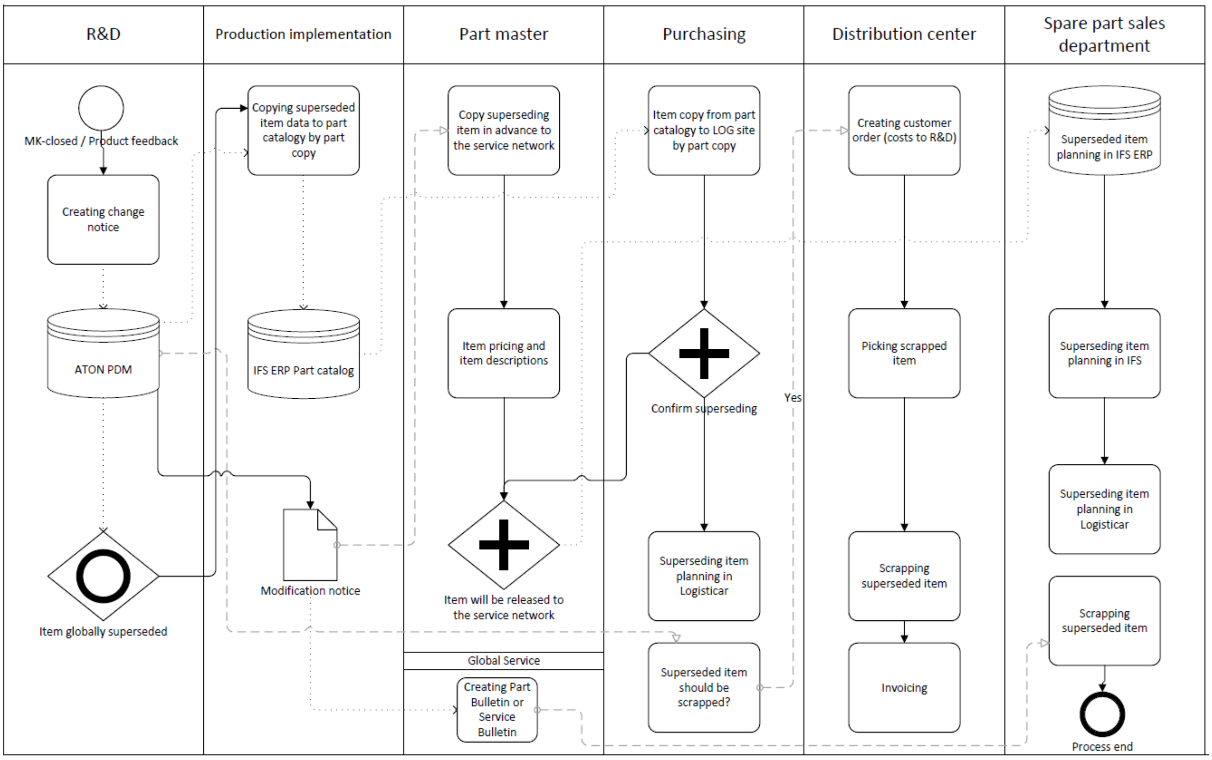

Figure 36 Item superseding process in the case company

Based on observation and interviews overlapped and slow-moving items are caused because the process is not used in the right way. It is noteworthy that the process was not modeled and responsibilities were not clearly understood. There are many tasks that need to be informed for the person who is responsible for it. Spare parts team have ordered new item although an old item is not superseded. This is often due to the neglect of superseding processing. Other reason could be that spare parts managers do not trust the process and they think that new parts are always superseding. The problem is that there might be many different revision of item stocked. The old version never meets demand because spare part sales departments are selling the new one consciously.

As mentioned the company has to develop their products continuously, this caused revised structures in the machines. Assuming that the new items are not superseding for old items in previous structure leads it to increase a number of items. In order to satisfy customers the company has to stock all item revisions. That means more stocked items and more tied capital to inventories. In additional, the machines have delivered worldwide, and many local inventories have all these items in their stock. This issue what due to product changes and supersedes is illustrated in Figure 37, which describes benefits and results at global replacement. The global replacement for new product development decreases quantity of items. This decreases also stock items and thus stock value.

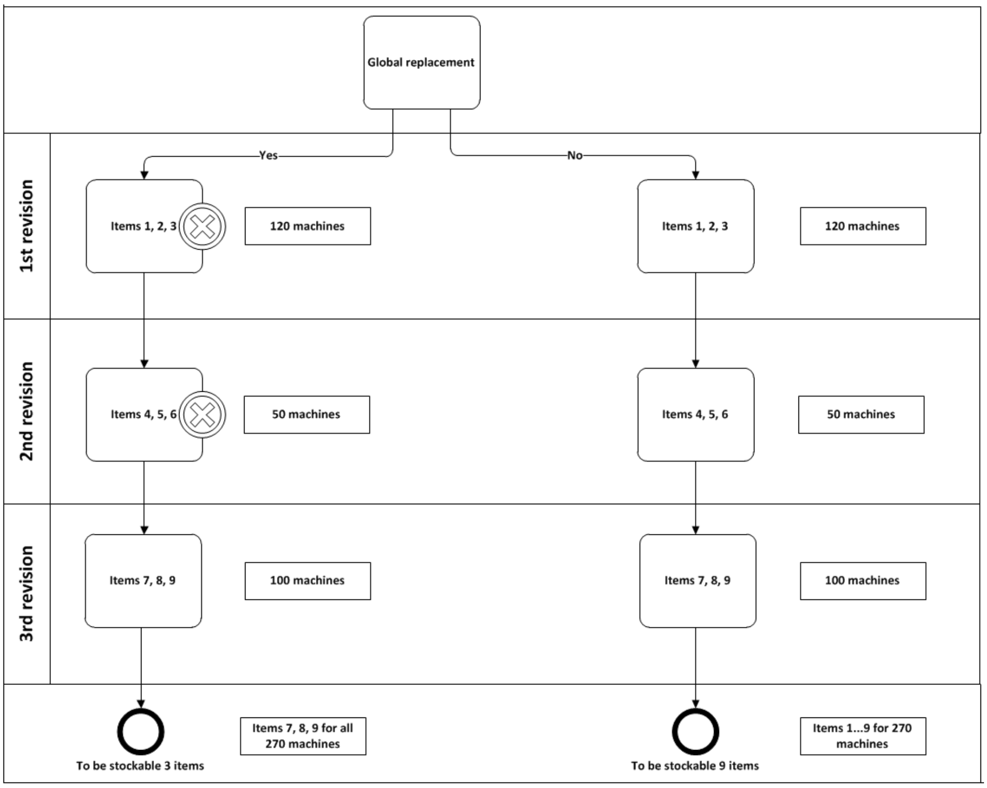

Figure 37 Simply example about global replacement's effects to item assortment

3.7 Spare parts return policy

In the multi-echelon inventory system, it is reasonable to stock items, which have demand in the network. When slow-moving parts or non-stockable parts are lying in stock somewhere in the network, it is not ideal from financial point of view. These parts are a reasonable stocking centralized in one place, which is commonly the distribution center. If demand is met, part is possible to dispatch to the destination.

The case company is running spare parts return from service sites to the distribution center twice in a year. CMI team, which manages global materials management in the company, provides the return proposal for each subsidiary. The proposals are based on demand data. A local spare parts team checks the proposal list and respond it back. The local spare parts team can proposal also items which would also be reasonable to return after that CMI team approves the final list. Then local spare part team makes a customer order to the distribution center. The parent company credits customer order based on inventory value cost. Consignee, subsidiary, will arrange a delivery and bear the freight cost to the distribution center. The whole process is illustrated in Figure 38 as a process map.

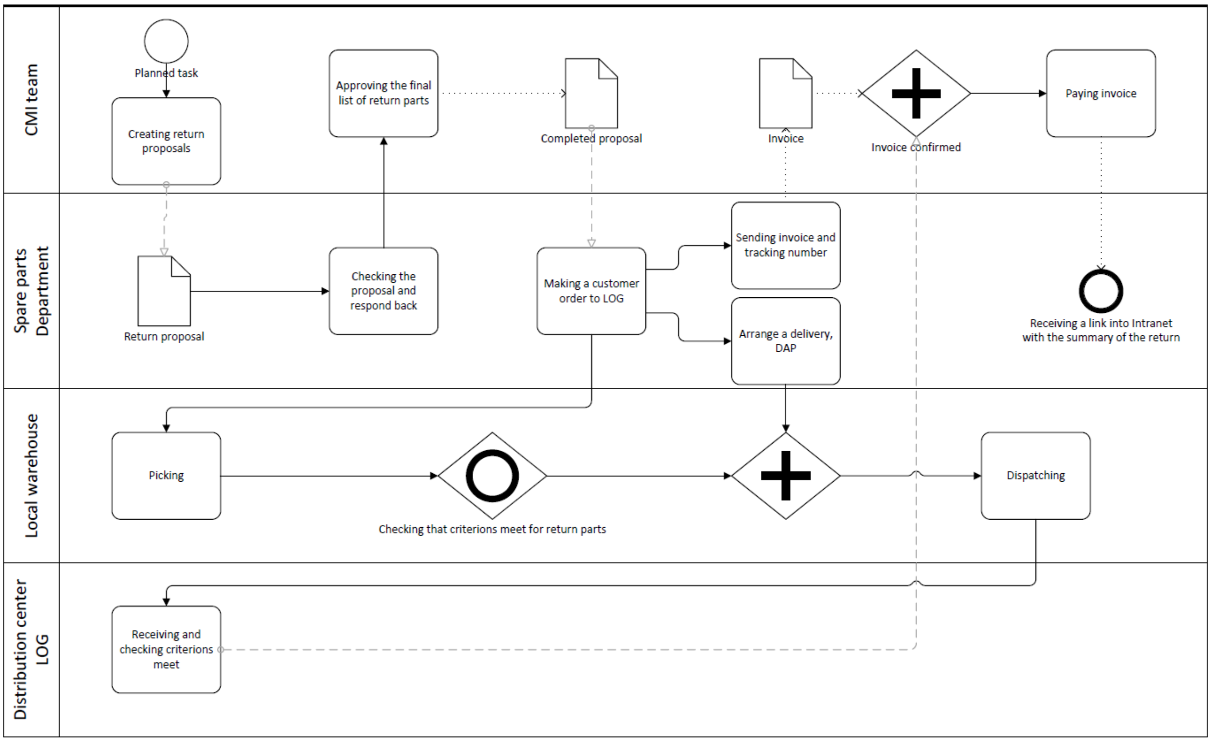

Figure 38 Described the current return process

Returns are managed twice a year with every subsidiary. All returned parts are subject to inspection. Final approval will be made after the warehouse inspection. There are several criteria, which should meet for all the returns. Returned parts must be packed in original packaging and have to be in sales condition. Also, part numbers and barcodes have to exist and show properly. Items must be purchased from the case company's warehouse. When parts are packed to pallets or boxes, they must have a pallet specific packing list and have the parts return tag in order to help discern pallets in the distribution center.

3.8 Down-write policy in subsidiary network

The case company does down-writes at the end of fiscal year to its inventory network. The purpose of the down-writes is to reduce slow-moving items value from balance sheet value.

Thus, the downwriting affects to the valuation of stock value. However, the down-writes affect negatively to the profit and loss statement. If item meets demand again in the future, then the current inventory value will be evaluated with a weighted average value. The case company's down-writes policy for slow-moving items is divided into three stages of rules:

1. Items with no turnover for 1-2 years will be down-written by 30 % of the asset value.
2. Items with no turnover for 2-3 years will be down-written by 50 % of the asset value.
3. Items with no turnover for more than three years will be down-written to a value of 0,01 euros.

In the year of 2016 down-writes was 4,6 percent of total spare part inventory value in the case company group. Down-writes are a character of poorly managed inventory management. In Figure 39 is illustrated down-writes in scope of thesis sites in year 2016. The figure illustrates that down-writes are high especially in service center sites (ASE and MII). In the distribution center (LOG) down-writes value of the total inventory value was the lowest. This describes well the current efficiency of inventory management. These slow-moving items, which have down-written, would have returned to the distribution center or local warehouses earlier.

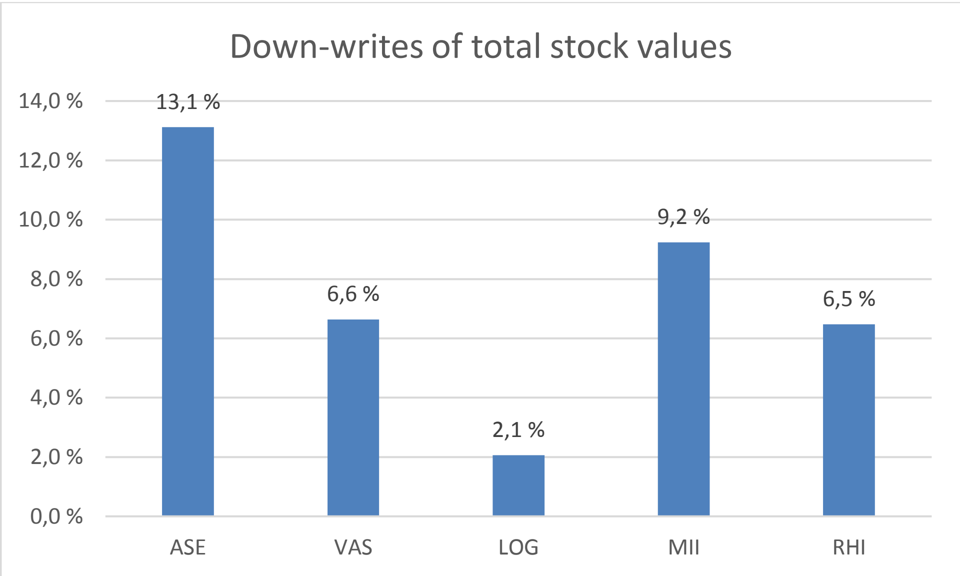

Figure 39 Down-writes of total stock value in 2016

In the bigger picture down-writes has been every year such a high level. In the last five years, down-writes have been approximate 18 percent of total stock value. Figure 40 shows that down-writes are a significant loss for company profit yearly.

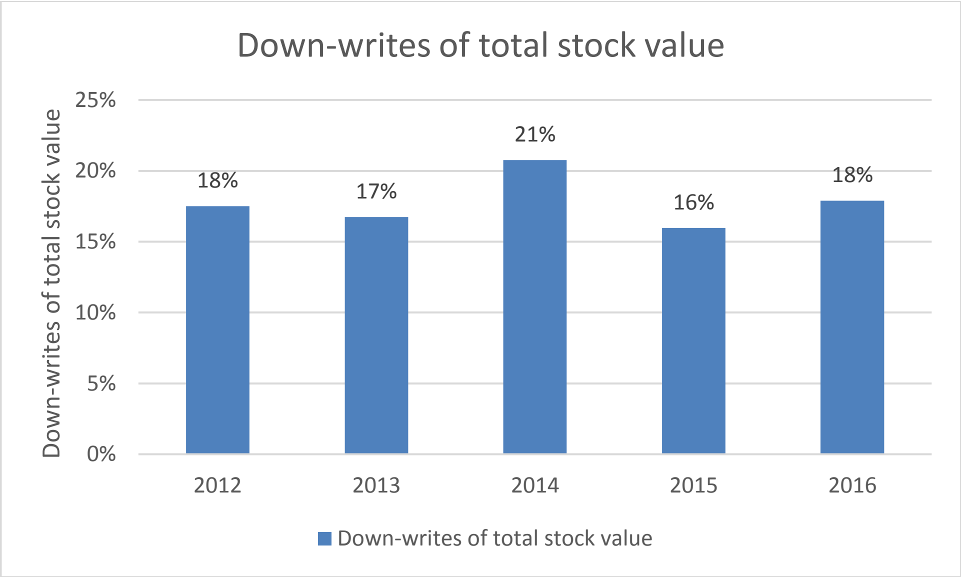

Figure 40 The development of down-writes in spare parts inventories

Figure 41 shows down-writes history and availability improvement in last five years in NA and AB subsidiaries and also in the distribution center during 2013-2016. In NA yearly down-write value has been approximate 6,3 percent of the total stock value. In AB it has been 6,8 percent of the total stock value. The distribution center has down written around 1 to 2 percent of the total stock value during two last year. Down-writes reflect quite well the waste of inventory management. They are directly loss from company profit. There is not straight solution how to decrease the waste though it is moreover phenomenon of poor inventory management and processes.

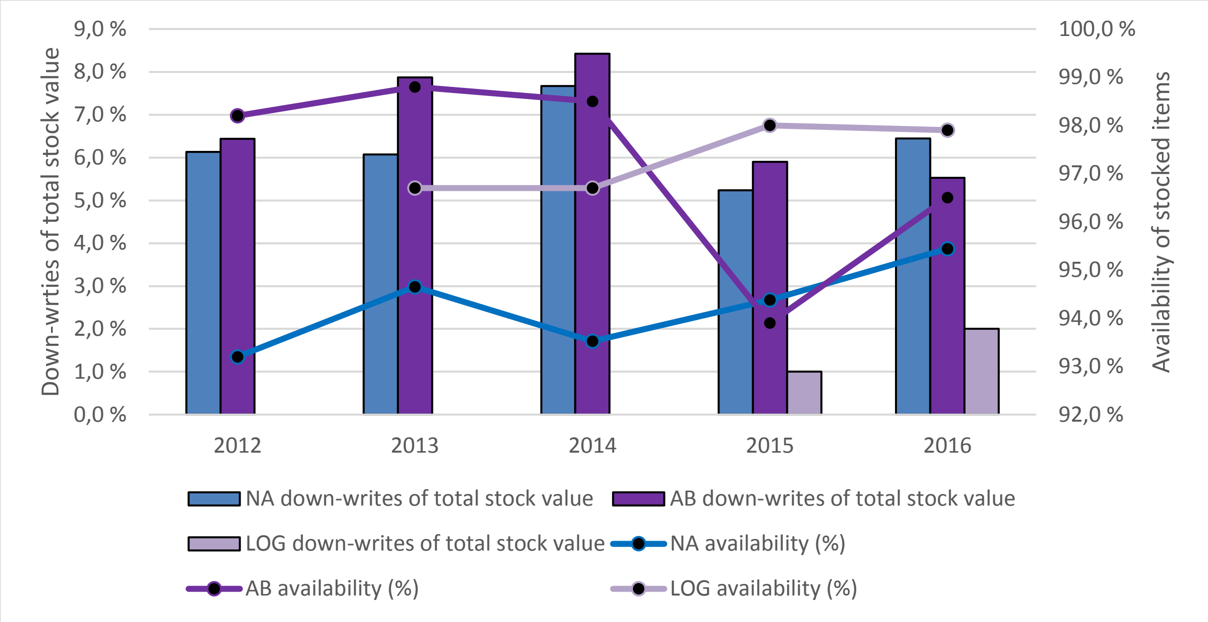

Figure 41 Development of down-writes and availability in AB, NA and the distribution center

3.9 Spare parts recommendations

The case company publishes spare parts recommendations for new machine models. The idea of the recommendations is to evaluate what items might be critical or need to be stocked at the local level. Primary objective of the spare parts recommendations is to ensure high service level. Recommendations are published as part lists which help to create base spare part stock for new machine models. Spare part recommendations is also created to help founding new service sites.

Spare parts recommendations are divided into three categories based on local machine fleet size. Three classes are standard, extended and central quantity. In Figure 42 is described current structure of spare parts recommendations.

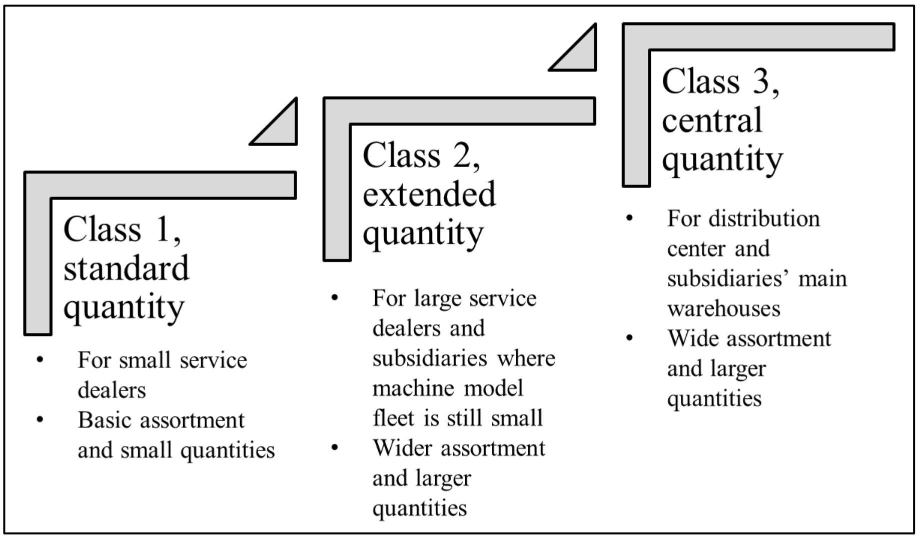

Figure 42 Spare part recommendation classes

Recommendations are based on expert judgments and the quantities given in recommendations based on previously stated classes with a multiplier of three between classes. For instance, if installed quantity of items is four then standard quantity is four, extended quantity is 12, and central quantity is 36. Spare part recommendations have seen problematic from inventory management point of view because a significant part of recommended items will not meet demand. However, the global service network want to prepare for new products and those spare parts needs. Unfortunately, the current spare part recommendation model affect many times non-moving and overlapping stocks worldwide because expected need for recommend spare parts will not realize. By analyzing spare parts recommendations, there was approximately 11 percent of all recommended parts that have met demand three time or less, but items are stocked in warehouses globally. Spare part recommendations have caused the bullwhip effect the whole global supply chain because demand has been high at the beginning of product life cycle. In reality, system has seen only internal demand, not end customers' demand. Thus, system has overcalculated the supply. The spare part recommendations have not corrected later with demand data and issue has increased.

3.10 Current demand forecasting

In the case company, demand forecasting is based only on 12 months average demand. Every day demand affects to the calculation of average value. This has seen problematic because there might be items which demand may be seasonal or peaky. A real demand can change rapidly, but a material planning system does not take account the last change enough. This leads that items which have peaky or seasonal demand they always have too low or too high stock level and many times just wrong time, especially in seasonal items.

As mentioned in literature review there are many different forecasting tools and methods which are helpful to estimate future demand when we know the item's past demand data. Time series methods are the most used for intermittent demand as spare parts. For seasonal or trend demand items, there are forecasting methods which take account seasonal changes to the forecasting. (Bacchetti & Saccani 2012, p. 722) On the other hand, there are also spare parts which are not necessary needed any special forecasting because items demand pattern is high moving and very smooth. (Simchi-Levi et al. 2008, p. 59)

3.11 Data analysis of current state

In this section will be described the current state of inventories by doing data analysis. As earlier is determined this thesis focuses on the distribution center and two subsidiary company and their focused sites. The data is gathered from the case company's ERP system and material planning system. Inventory data is based on the last 12-month transactions.

3.11.1 Inventory analysis

The case company's average stock value is calculated from the last 12-month every day actual stock value. The stock value is evaluated on the value of the weighted average purchase value. The Cost of Goods Sold (COGS) is based on items usage at purchase cost. Also, inventory turnover basis on 12-month average stock value and COGS. As earlier noticed company calculates values for availability and service level. Availability means how many stockout items of all stocked items there are available in stock when the report is taken. The service level is more service-oriented measurement; the service level means how many stock out items have met demand of all stocked items during 12 months period. Table 10 illustrates these inventory data. In following sections are focused each of them.

Table 10 Basic inventory data of warehouses (absolute values are encrypted because of confidential reasons)

	ASE	VAS	LOG	MII	RHI	Total
Average stock value	-	-	-	-	-	-
% of total average stock value	0,9 %	6,8 %	74,2 %	4,5 %	13,6 %	100,0 %
Cost of Goods Sold (COGS)	-	-	-	-	-	-
% of total COGS	0,6 %	5,8 %	77,9 %	2,8 %	12,9 %	100,0 %
Total inventory days of supply (TIDS)	221	155	125	206	139	132
Inventory turnover	1,7	2,4	2,9	1,8	2,6	2,3
Availability (%) (stockable items)	94,6	98,6	97,4	96,8	95,4	96,6
Service level (%) (stockable items)	96,7	99,1	98,2	98,1	97,7	98,0

Table 11 describes the overall situation by ABC categories (all thesis scope sites), the 12-month sales value, average stock value, the cost of goods sold value (COGS), turnover rate and total inventory days of supply (TIDS). Total inventory turnover is 2,6, and then TIDS is 191 days. A class performs the best turnover rate 5,4. Other classes turnover rate range from 4,1 to 0,9. F, G and H classes, which make up only 10 percent of the total consumption, have items in stock on the average range from 229 days to 415 days. These classes tied invested capital to stock 22 percent of total value. It is also noteworthy that the middle classes (C,D,E) cause 37 percent of total stock value and generate 40 percent of total consumption. As literature says that the middle classes are problematic because there is remarkable proportion of total amount of item quantity. There are a large amount of expensive items and a lot of cheap items which are purchased in bigger order lots.

Table 11 Overall ABC summary of sites inventory data (absolute values are encrypted because of confidential reasons)

ABC class	Sales value	% of total	Average stock value	% of total	Cumulative value of total stock value	Cost of Goods Sold (COGS)	Inventory turnover	TIDS
A	- €	30 %	- €	15 %	15 %	- €	5,4	69
B	- €	20 %	- €	12 %	27 %	- €	4,1	90
C	- €	15 %	- €	11 %	38 %	- €	3,0	130
D	- €	15 %	- €	13 %	52 %	- €	2,6	147
E	- €	10 %	- €	13 %	64 %	- €	2,0	185
F	- €	5 %	- €	8 %	72 %	- €	1,6	229
G	- €	3 %	- €	6 %	79 %	- €	1,4	262
H	- €	2 %	- €	8 %	87 %	- €	0,9	415
I	- €	0 %	- €	13 %	100 %	- €	-	-
Total	- €	100 %	- €	100 %		- €	2,6	191

3.11.2 Availability analysis

In the previous section is discussed about problematic middle classes. As Table 12 shows there is the best availability in these classes. As literature says, it is expensive to keep up high service level for every class. In additional there are large amount of items which are high value items but also quite new items with good turnover. Service level is a better indicator to describe the real service level from a customer point of view. C class has the highest service level, 99,0 percent.

Table 12 Total average availability and service level in sites

ABC class	Availability % (Availability / 0-lines)	Service level % (Availability / demand)
A	93,4	97,7
B	93,0	96,2
C	96,5	99,0
D	94,7	97,9
E	94,7	97,2
F	97,4	98,1
G	96,8	98,2
H	97,5	98,3
I	80,8	100,0
Grand Total	**93,9**	**97,9**

The high classes should be planned that both the availability and service level would be the highest level of all classes. The case company wants to provide high availability of spare parts that explain why middle classes tied the huge amount of capital (see Figure 43).

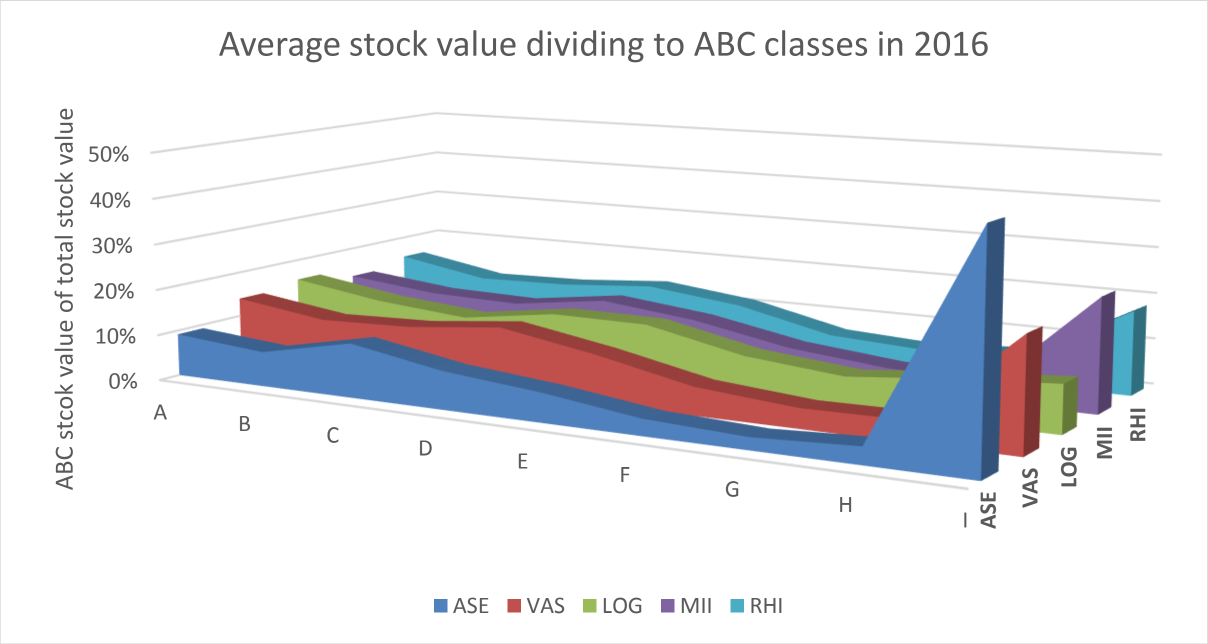

Figure 43 ABC classes stock value of total stock value - middle classes stock values are remarkable high

3.11.3 Slow-moving items analysis

The case company does not use sales intensive codes in item planning. The case company's stocking policy bases on pick ups but otherwise SIC analysis are not utilized. In academic literature it is known better as XYZ analysis. XYZ analysis helps to identify demand pattern by frequency of usage. In this analysis items are classified to XYZ classes according to 12 months pick ups. Classification ranges are determined by pick ups in last 12 months. On Table 13 is described stock value of XYZ classes.

Table 13 XYZ analysis bases on transactions frequency, pick ups from stock

Pick ups	SIC (XYZ classification)	ASE	VAS	LOG	MII	RHI	Total	
		Of total stock value	Of total stock value	Of total stock value	Of total stock value	Of total stock value	Of total stock value	Average
≥30	**X**	2,8 %	8,2 %	33,1 %	5,5 %	13,7 %	27,4 %	12,7 %
11-29	**Y**	6,3 %	15,0 %	18,1 %	12,4 %	15,9 %	17,2 %	13,6 %
5-10	**Z**	6,0 %	16,6 %	16,7 %	10,8 %	15,0 %	16,1 %	13,0 %
3-4	**zz**	7,3 %	11,6 %	7,9 %	11,4 %	11,0 %	8,7 %	9,9 %
1-2	**L**	29,2 %	20,3 %	12,0 %	29,1 %	21,2 %	14,7 %	22,3 %
0	**N**	48,4 %	28,3 %	12,2 %	30,9 %	23,2 %	15,9 %	28,6 %
	Grand Total	100,0 %	100,0 %	100,0 %	100,0 %	100,0 %	100,0 %	100,0 %

Slow-moving analysis shows that slow-moving class, L, generates approximately 22,3 percent of total stock value. According to the case company’s stocking policy these items should not be stocked. Particularly in ASE site non-stockable items (classes L and N) generate 77,5 percent of total stock value. Also, other branch warehouses carry significantly amount of non-stockable items in stock. LOG site carries only 12 percent of total stock value in L class. Remarkable observation about this analysis is that approximately 31 percent of total stock value is tied to non-stockable categories (L and N). One factor to be taken into consideration when evaluating items with zero pick ups and without any transactions, that there are entirely new spare part items also. In the next section is focused to analyze the non-moving items.

3.11.4 Non-moving items analysis

Table 14 illustrates non-moving stock values in thesis project’s scope. This analysis is done using ABC classification what is currently used in the case company. Non-moving items mean I class items, which do not have any demand in last 12 months. In this examination, have taken account I class items, which are received to stock earlier than 1.1.2016. This is done because there can be entirely new items or campaign items which have not had any demand yet. This approach describes better the real dead stock value in the case company’s issue.

Table 14 Non-moving analysis (absolute values are encrypted because of confidential reasons)

Site	I class items in stock (received earlier than 1.1.2016)	All items in stock	I class items (received earlier than 1.1.2016)of all items	I class value	A-I classes average stock value	I class value (received earlier than 1.1.2016) of all items value
ASE	2197	4372	50,3 %	- €	- €	35 %
VAS	3114	7589	41,0 %	- €	- €	20 %
LOG	3015	19336	15,6 %	- €	- €	7 %
MII	2995	7572	39,6 %	- €	- €	21 %
RHI	2712	11796	23,0 %	- €	- €	13 %
Total	-	-	33,9 %	- €	- €	19 %

In December 2016 these sites total I class value was 19 percent of total stock. The highest I class value was in ASE site, 35 percent of the total stock value and every second item were in I class. Overall in this scope, every third item was in I class (33,9 %) (see Figure 44). Remarkable is that the distribution center had the lowest level of non-moving stock value. This refers to worse managed non-moving items return process and the lack of inventory management in service sites. This observation supports findings of interviews with spare part personnel. Also as the literature review recommends that only locally high-moving spare parts, low-price items, and critical items for machines processing should keep stocked near the customers.

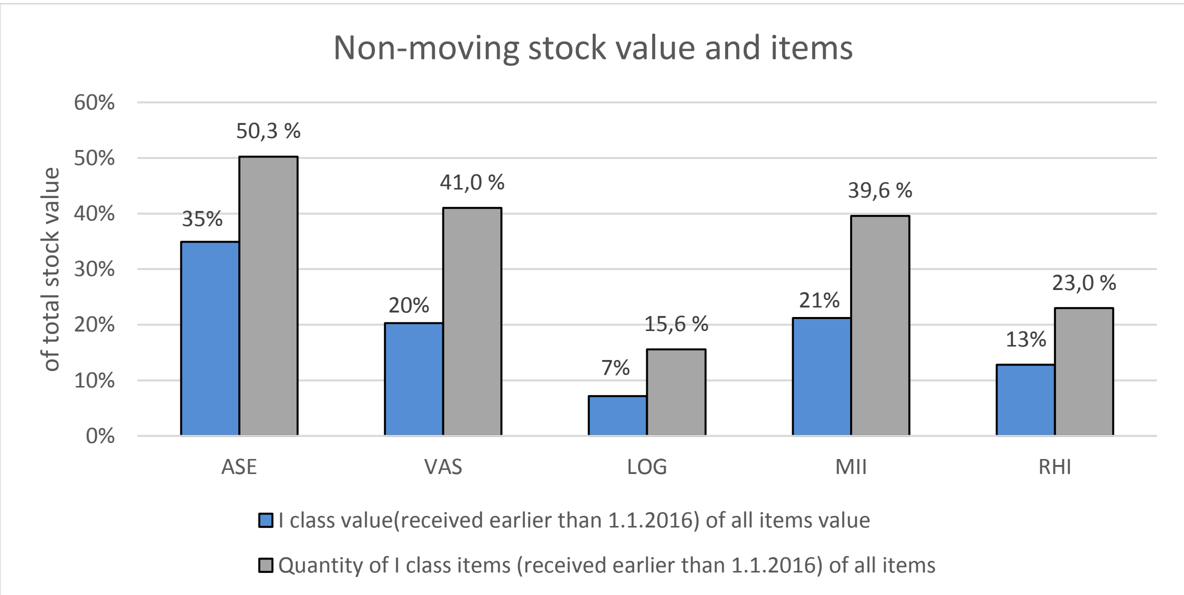

Figure 44 Non-moving stock analysis by value and item quantity

Figure 45 illustrates non-moving stock relationship to service level and availability. The more telling indicator is the service level because it illustrates the real availability of needed spare parts. Comparing these indicators can be seen as the efficiency of inventory management. For example, ASE site has the highest non-moving stock, 35 percent of the total stock value, but the service level of stocked items is the lowest. On the other hand, the distribution center (LOG) has the lowest non-moving stock, 7 percent of the total stock, but the service level is second highest. If the global spare part supply chain performed more efficiently, non-moving items should be stocked at the upstream of the supply chain. Then items would be available for global demand when overlapping and non-rotative stock value would be less. By using this kind of analysis it can be seen how well inventory management is performing at the global level.

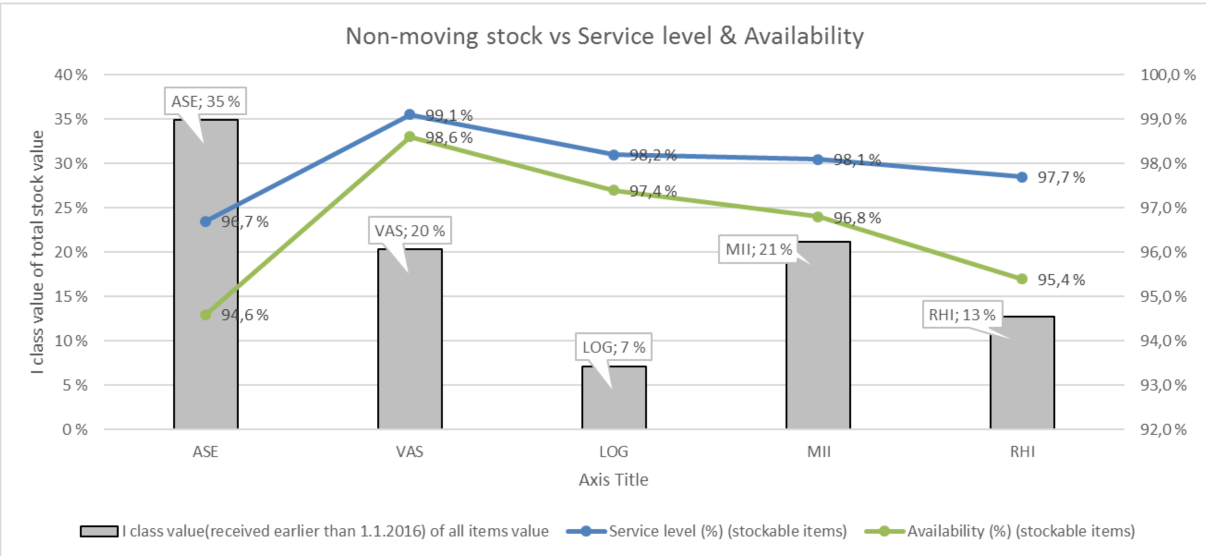

Figure 45 Non-moving stock value comparison to service level and availability

Figure 46 illustrates the non-moving stock value of total stock value and inventory turnover in each site. This figure shows very well the current state of item planning and inventory management. Remarkable factor for poor inventory turnover forms from a non-moving item in stock. Particularly ASE site has poor turnover rate and same time 35 percent of stock value is in non-moving stock, which is called as “deadstock” also.

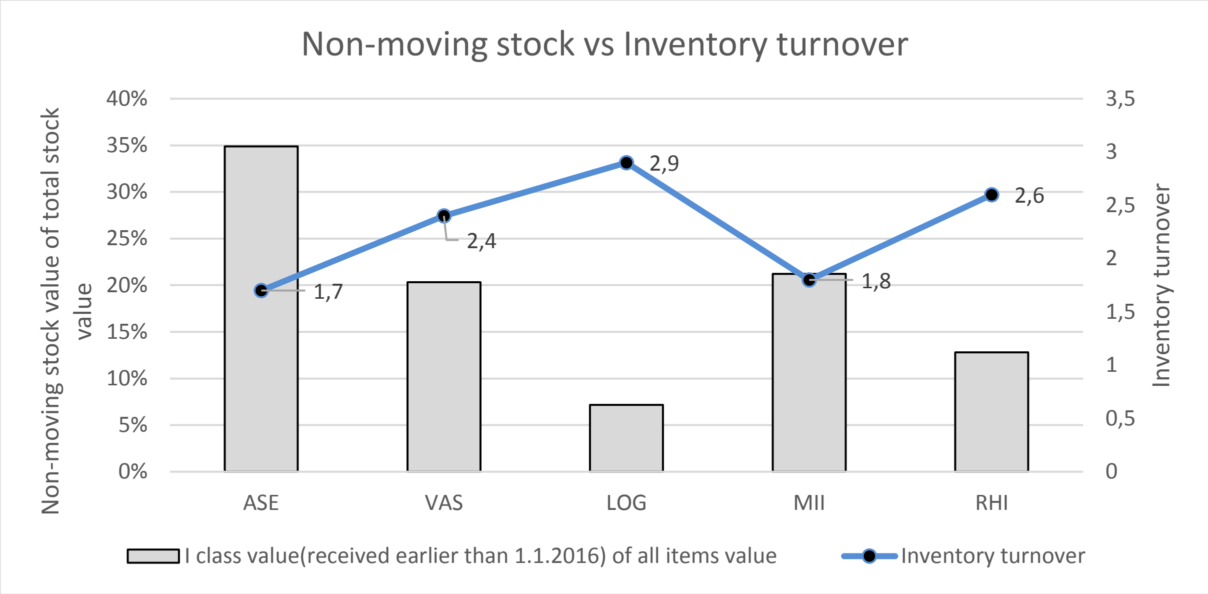

Figure 46 Non-moving stock value comparison to inventory turnover

3.11.5 Inventory turnover analysis

The main objectives of inventory management are to get inventories rotated and ensuring sufficient service level for customers. Figure 47 shows an average turnover rate of the examined sites in different classes. There is described average stock value and turnover by classes. A class has the best turnover rate and the highest stock value. As previously is noted the middle classes are problematic as there can be seen that stock values of D and E classes are extremely high level, but there is no corresponding benefit for inventory turnover rate.

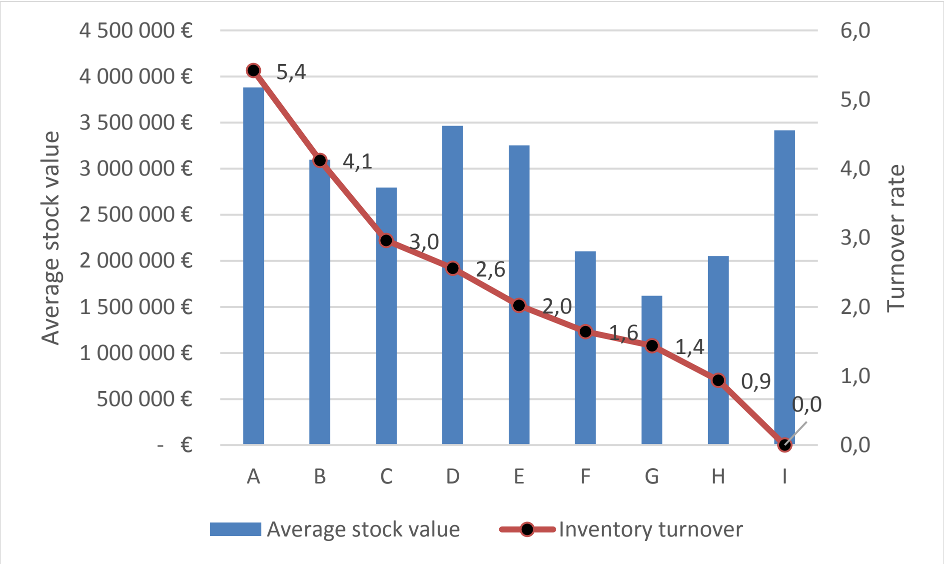

Figure 47 Corresponding of inventory turnover rate and average stock value

On the other hand, high stock value does not necessarily guarantee significant better service level. This can be seen in Figure 48. The highest service level is in A class and then the service level is developing very linearly except category B where the number of stockouts has been significantly higher during last 12 months.

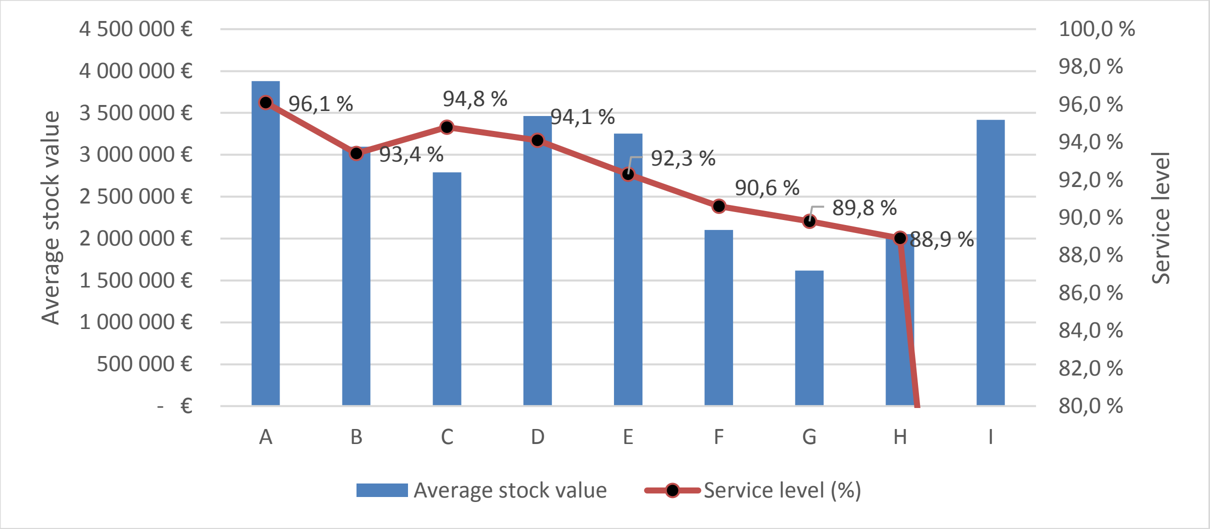

Figure 48 Connection between stock value and service level in sites inventories

When looking the development of turnover rates, there is deteriorating trend in all sites. Especially RHI's and ASE's inventory turnover has weakened during last two years. In additional, in general can be seen from Figure 49 that the trend in the turnover rate is declining. Overall, this explains clearly the challenges of inventory management.

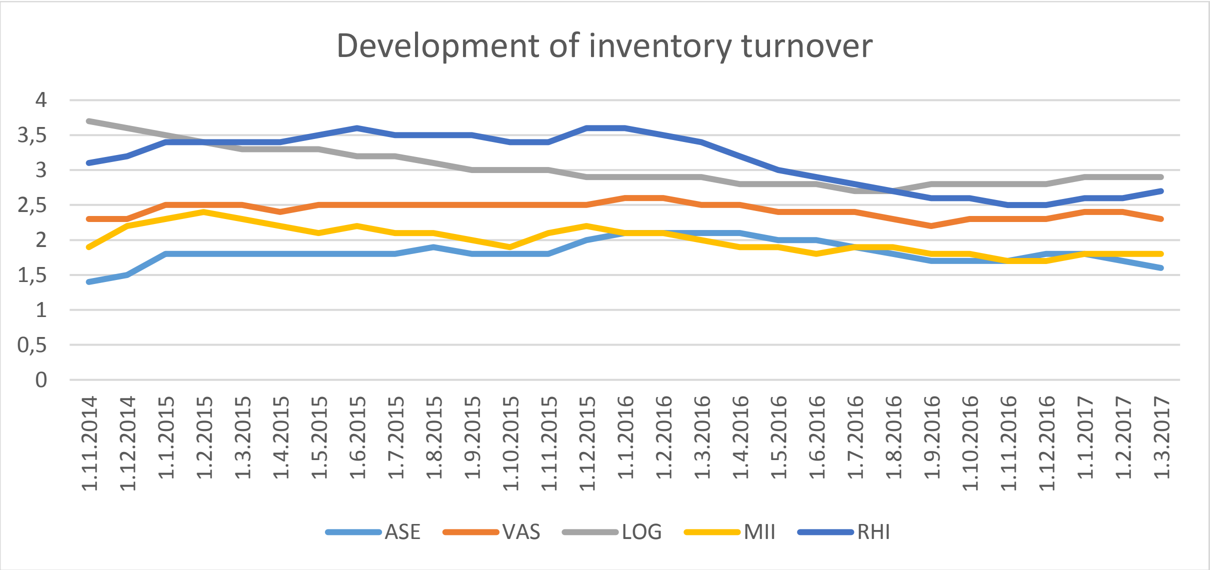

Figure 49 Development of inventory turnover rates

3.12 Conclusion of current situation

Currently, the case company inventory structure is as academically known a multi-echelon inventory system, which is a standard requirement in the global spare part business. Subsidiaries order items from the distribution center and at the local level they have main warehouses where they distribute spare parts inside the subsidiary to other service sites. The whole inventory system is based on the continuous review system, that is managed with inventory managing concept, which is called as Centrally Managed Inventory, CMI system. There are ERP system and material planning system for item planning, inventory replenishment, product policy and items superseding.

Item categorization is based on ABC philosophy. There are nine ABC classes where items are taking place regarding sales volume. For these classes are set a target service level and turnover and based on these targets the material planning system calculates reorder point, order quantity and stock level for each item. ABC classification is commonly used and also noticed by academic literature. Stocking decision is based on pickups during the last 12 months. In the product policy, material planning system proposes which items should change stockable and non-stockable. The local spare part team can deviate from the policy if some spare parts want or not want to keep in stock.

Future demand forecasting methods are not so well used in the case company. The material planning system is doing continuous item planning based on the last 12 months demand. Spare part demand is known about intermittent demand, as the literature says, it is much more difficult to forecast than make to order manufacturing for example. There could be useful to use time-series based methods to forecast demand using the past data. This is mentioned one of the future development tasks in the case company.

One of the biggest issues in the case company is the performance management. There is not clear process based performance management and performance measurement for inventory management. In particularly a lack of measurement on the operational level is the biggest challenge at the moment. There is only a yearly internal audit where are few evaluates for inventories, but locally personnel is not following those so well. As literature says, if there are not performance measurement and targets, they will not be achieved (Waters 2003, p.

197; Richards 2011, p. 230). There are budget-based targets for inventory management for each subsidiary, but a target setting to the lower level for each site are missing. In additional, there should be plans and actions how to achieve the targets, and a continuous follow up for actions and goals. In practice, this means there are not even key performance indicators, as performance scorecard and process-based performance management in place.

Current state analysis raised the problem with the spare part recommendations. The case company creates recommendations of spare parts for new products. Because recommendations are based only expert judgment by service department they causes many times non-moving and overlapping stocks worldwide. Assumed consumption will not be realized and then recommended spare parts constitute dead stock and bullwhip for the supply chain. The bullwhip effect is caused because the distribution center has high demand at the beginning of the product life cycle and then item planning is overcalculated. On the other hand, spare part recommendations are not updated continuously, and the problem will be more complicated when the company establish new service sites and create base stock using by spare part recommendations.

The case company strives to standardize product models at the same time when company develops products. Due to continued product development, there is designing new items which affect to spare part assortment. Increasing spare part assortment is problematic because then both new and old item must be stocked. Because of this the case company aims to design new items that old parts can be replaced with new parts. Global replacement is more and more mandatory when new products and modifications are designed. Collaboration between functions and understanding of spare part management is remarkable when are designing new machines. Item superseding makes possible to decrease stocked items quantity and stock value also. This issue is one of the major things what comes to spare part life cycle management.

As academic literature says about stocking locations it is important to stock spare parts there where consumptions are. Thus, the case company has spare parts return process for non-moving items. The idea of the returns is to move non-moving items from branch warehouse to distribution center where items are available to whole network. Currently return of parts is done bi-annually for each warehouse. Proposals are done by manually and there are a lot of work with those. From the material flow point of view, it would be better to increase the frequency of parts returns and do it more automatically process by using information systems.

In the data analysis is investigated the performance of selected stock locations. There are done basic inventory analysis such as availability, slow-moving, non-moving, turnover rate and cross-checking analysis. The major result of analyses was non-moving stock value and its share of the total stock value. In this thesis scope non-moving stock value of total stock value is 19 percent. In addition, 34 percent of all items are in non-moving class. Remarkable issue was that highest non-moving stock value were in branch warehouses. Also, turnover rates were at the worst level in the branch warehouses. Commonly in literature reviews say that turnover should be the highest nearby end customer rather than the distribution center.

4 RESULTS

4.1 Multi-criteria classification

The case company controls items currently with ABC classification where are nine classes, and classification is done by using annual sales volume including margin value. In this thesis project is observed that it would be more efficiency to control items with supplementary classification method. XYZ analysis reveals items frequency of transaction and describes better how usually items are needed. Based on XYZ analysis there is determined sales intensive codes (SIC) X, Y, Z, zz, L and N. In Figure 50 is illustrated pick up quantities and ranges for each codes. Pick ups are also called as annual sales transactions. In the new model, there is decreased quantity of ABC classes from nine to three. Nine ABC classes are not necessary anymore because there is added SIC classification and using two criteria makes controlling and planning much more focused and efficient. The new items classification model is illustrated below.

		Percentage of the annual total cost of goods sold (COGS)		
Pick ups	**ABC / XYZ**	**A 80 %**	**B 15 %**	**C 5 %**
≥30	**X**	*AX*	*BX*	*CX*
11-29	**Y**	*AY*	*BY*	*CY*
5-10	**Z**	*AZ*	*BZ*	*CZ*
3-4	**zz**	*Azz*	*Bzz*	*Czz*
1-2	**L**	*AL*	*BL*	*CL*
0	**N**	*AN*	*BN*	*CN*

Figure 50 The new items classification model for the case company

The new classification model makes possible to observe and handle easier slow-moving items (class AL, BL, CL). Earlier the case company used ABC classification for spare parts and that causes management problem with middle classes where are many items which generate a significant amount of stock value. With the new classification model items can be categorized into classes in order to control and plan them more accurate and efficient. In addition, inventory analyzing is more focused and makes easier to make policies for different classes. Company's current stocking policy will remain same as the past in the new model. If item has had three or more pick ups in the last 12 months then item will be stocked. If fewer than three pick ups, then item will be non-stockable.

By using the multi-criteria classification matrix it is easier, more economical and reasonable to target the mathematical service level for each category. As literature earlier said, it is not reasonable to put same service level target for all classes. Thus, it is economical to give the highest service level target for high moving classes such as A class. On the other hand, especially C class has a lot of cheap items whose effect to stock value is not remarkable, and they are ordered within big order lots. TIDS of these categories is high so stockout is unlikely. In Figure 51 is proposed service level targets for item classes.

		Percentage of the annual total cost of goods sold (COGS)		
Pick ups	**ABC / XYZ**	**A 80 %**	**B 15 %**	**C 5 %**
≥30	**X**	*98,0 %*	*99,0 %*	*99,8 %*
11-29	**Y**	*97,0 %*	*98,0 %*	*99,8 %*
5-10	**Z**	*95,0 %*	*98,0 %*	*99,8 %*
3-4	**ZZ**	*95,0 %*	*96,0 %*	*98,7 %*
1-2	**L**	*50,0 %*	*50,0 %*	*50,0 %*
0	**N**	*50,0 %*	*50,0 %*	*50,0 %*

Figure 51 Mathematical service levels for item categories

4.2 Continuous parts return policy

In section 3.11 is analyzed slow-moving inventories (section 3.11.3) and non-moving inventories (section 3.11.4). Analysis showed that there are a huge amount of items stocked which should not be stocked in inventories by product policy. Class L (slow-moving class) includes items, which are picked up once or twice during 12 months. This class generates approximately 22,3 percent of total stock value. Non-moving items are all items in stock without demand or pickups in 12 months. Class N creates approximately 28,6 percent of total stock value in stocks.

Earlier parts return is done twice in a year for each site. Thus these items should be returned more often because items which were not needed and it does not make sense to keep them in stock. Parts return could be done quarterly and returned parts should be listed automatically by material planning transaction. The system would calculate items which would make sense to return to the distribution center. The new main rules for the returned items are:

- Non-stockable
- No demand or need exists
- At least three months in the stock
- Inventory value must be greater than 99 euros
- Item is active in the DC
- Non-campaign items

These previous rules take into account the new items which have not met demand yet. Also, new return policy excluding items which are planned manually and have not been in stock long time. In addition, campaign items will be excluded from the return policy. However, items should be as active in the distribution center, and inventory value of the item must be greater than 99 euros.

Continuous parts return policy enables that returns could be scheduled so the workload rate in the distribution center would be better managed. It also decreases the peak of workload and balances it between returns. On the other hand, continuous parts return process provides more efficient material flow to upstream of the supply chain. It provides better performance and productivity for inventories when there are stocked only items which have needs or demand. The continuous parts return processing will lead to better inventory turnover and lower stock value because slow-moving and non-moving items stock value is lower than earlier. This decrease globally overlapped inventories and give better capital turnover for the company. In additional, it decreases bullwhip effect and the future waste of capital when are downwriting non-moving items.

4.3 Performance management and key performance indicators

As stated before the case company does not have process based performance management for the inventory management. There is not existing clear process model how to set targets for each service site and how to achieve the given targets by the actions. In addition, there are not key performance indicators what can be monitored and follow up constantly. Consistent target setting allows achieving objectives efficiently. Thus, there is created performance management model and determined key performance indicators for the case company as result of the thesis.

A target setting process is developed to run yearly in every subsidiary. In order to lead and develop inventory management, there is done systematic process for target setting and target achieving. The model includes responsibilities for each function. Cross-functional cooperation makes possible to get support and resources to achieve the given targets**.** In addition, information transparency and reliability are improving. The new performance management and target setting model is illustrated in Figure 52.

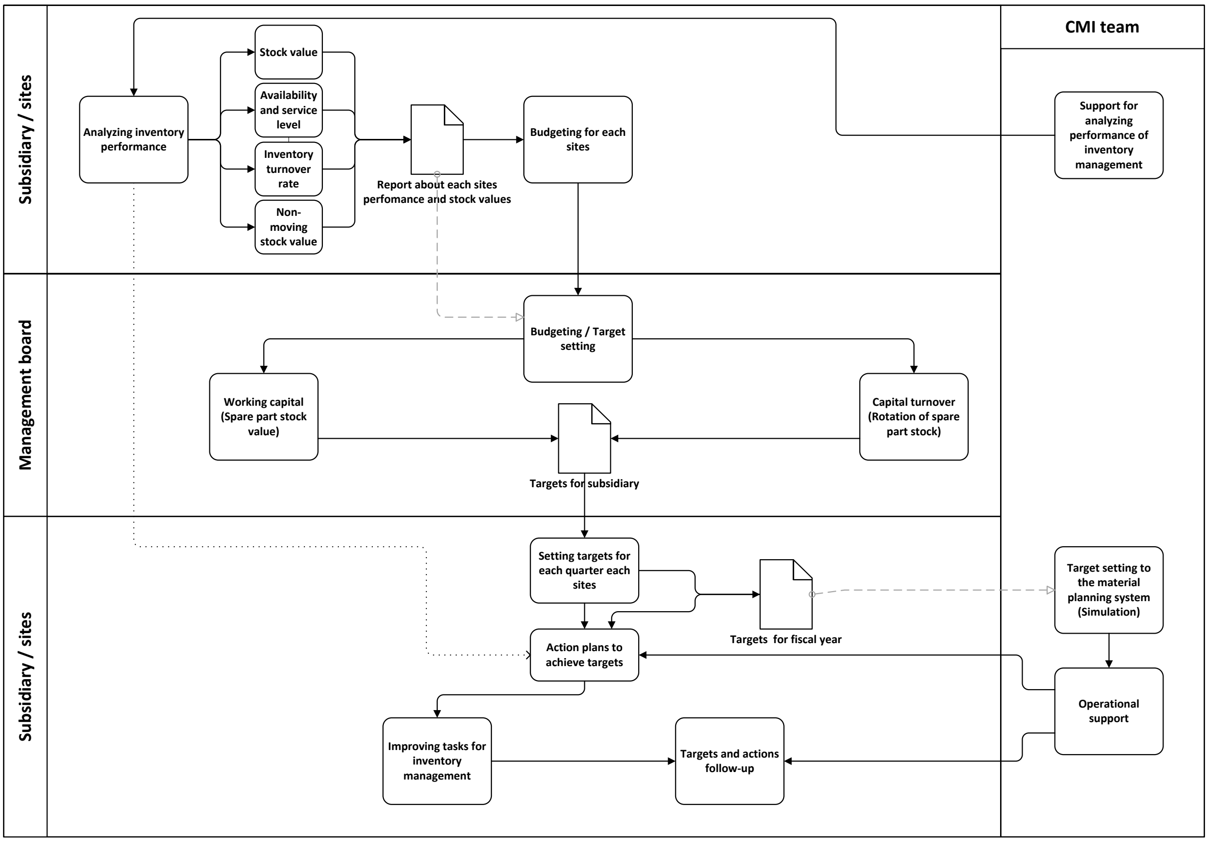

Figure 52 Budget based target setting for inventory management

In the new target setting model, the process begins with inventory performance analyzing. The idea of the first stage is to take into account inventory current state by data analyses. The CMI team supports to analyze inventory data and gives recommendations what things should be improved. Inventory management analysis includes availability and service level, inventory turnover and non-moving stock analysis. On the basis of analyses subsidiary creates a report to support target setting. If subsidiary has more than one inventory, then there are set targets for each inventory, which form a proposal for budgeting and target setting. In the management board meeting, the report supports decision-making and target setting. There will be given two targets regarding spare part inventories for each subsidiary. The given targets are total spare part stock value and inventory turnover for the subsidiary company.

Previously, one challenge has been how to achieve targets what management board has set for subsidiary. In the new approach model, there is set targets for each site and operational objectives how to manage inventories to reach them. CMI team put targets into material planning system that system can calculate inventory parameters and achieve targets. In additional, CMI team has the closer role of support local spare part department than before and help to improve inventory management. The idea is to find improvement objectives and make together action plans and tasks for the current year.

Current state analysis revealed that subsidiaries do not follow up any inventory management specific key performance indicators. Thus there should create key performance indicators what can be monitored regularly. Key performance indicators, KPIs, make easier to monitor performance. One result of the thesis is created KPI framework for the global materials management. The KPI framework includes inventory management specific KPIs and follow-up process and routines. In the next subsection is determined the most important and vital KPIs for the case company’s global spare part inventory management.

4.3.1 KPI framework for inventory management and follow-up practices

In the case company key performance indicators have not been in use for global inventory management. The purpose of KPIs cannot be underestimated when are managing global inventory network. As a result of the thesis is determined the most important KPIs for the case company in the field of spare part inventory management. In Figure 53, KPIs are categorized to main categories. Regarding inventory planning, working capital management, and customer service performance, the key aspects of spare part operations and inventory management are invested capital to the inventory, inventory rotation and service level. There are also created operational KPIs for CMI processing, order processing, and freight costs. As literature also mentioned, KPIs supposed to be wider reviewed. Therefore it is important to evaluate overall performance in the multi-echelon inventory system. As commonly noted, freight costs and inventory value affect directly to each other and the service level. Thus, there are considered these areas when described KPIs for the case company. It is also important to remember that when setting targets for KPIs, too high target for one KPI can influence to another performance indicator unacceptable.

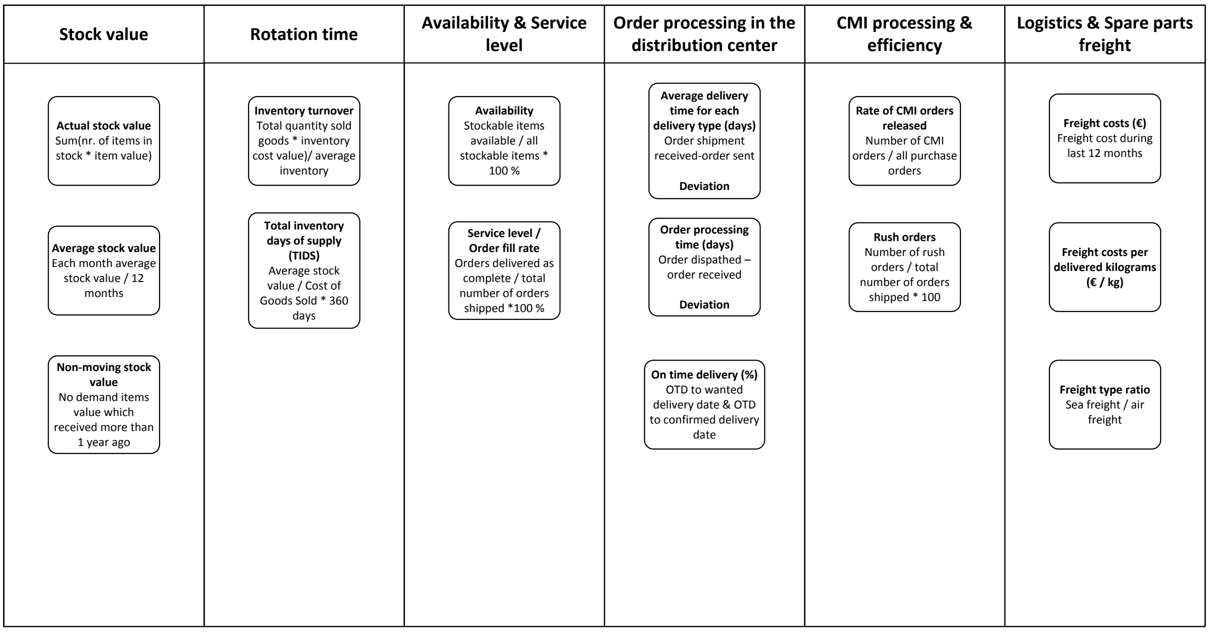

Figure 53 KPI scorecard for the case company

KPIs are defined to use mainly for the case company’s subsidiary spare part inventory management. KPIs increase information about performance and help to lead performance. Defined KPIs are chosen for current needs, and them continuous improvement is mandatory because needs will change in the future. For the future idea is to use these KPIs in the KPI scorecard software. This kind of solutions makes possible to review performance many ways.

The efficiency of inventory management and planning accuracy consist of many factors. A very fundamental key performance indicator is total stock value, what should measure continuously. The total stock value indicates very simple way tied capital to inventory. There are defined two indicators for stock values that are actual and average stock value. Actual stock value describes current day stock value. Second, average stock value describes average stock value from moving 12 months. KPI scorecard software provides possible to take a deeper view about stock value, for instance, it can be reviewed by ABC or XYZ classes. What comes to stock value measurement there is also created non-moving stock value measurement. This is done by showing “dead stock value”, which is calculated from items in stock which do not have any demand and check-ins during last 12 months. Thus can be evaluated stock value which is non-moving and not including new items.

The case company should also measure inventory activity that means a rotation of inventory. This can be done using inventory turnover rate, which is very practical and easy to understand. Inventory turnover rate is calculated as following:

$$Inventory\ turnover\ rate = \frac{Cost\ of\ Goods\ Sold\ (COGS)}{Average\ stock\ value} \tag{20}$$

Another measurement of inventory activity is total inventory days in supply (TIDS). It is commonly used in financial figures and reports, but the difference is not so huge compared to inventory turnover. In addition, it is very objective indicator, it tells how many days demand current inventory is able to supply. Total inventory days of supply is calculated as follows:

$$Total\ inventory\ days\ of\ supply\ (TIDS) = \frac{Average\ stock\ value}{Cost\ of\ Goods\ Sold\ (COGS)} * 360 \tag{21}$$

Service level and availability are mixed many times with each other. In the case company is wanted to monitor the availability of stocked item from stock and order fill rate which generates customer service level. Percentage of availability shows how many percents of stocked items are available in stock. From a customer point of view more important KPI is service level, which tells how many items that customers are needed were available. Availability and service level should be measured and monitored by total value and separately for different item classes. Availability and service level are calculated as follows:

$$Availability = \frac{Stock\ out\ items}{All\ stockable\ items} in\ 12\ mths * 100\ \% \qquad (22)$$

and

$$Service\ level\ = \frac{Ordered\ items\ delivered\ promptly\ from\ stock}{Total\ ordered\ items}\ in\ 12\ mths * 100\ \% \quad (23)$$

These KPIs do not reveal if orders are not delivered to the customer on time. Thus, this aspect should also be measured and exploit to share seamless information to the logistics provider or internally for the distribution center. KPI of on-time delivery (OTD) is divided into two features which are on time delivery to requested delivery date and the second is on time delivery to confirmed delivery date. These KPIs reveal how many of orders are delivered on time. For company’s internal order is also calculated KPI of on time delivery. It measures the efficiency of internal delivery process.

Relating to OTD indicator one very fundamental thing in the global delivery process is delivery time and its deviation. Especially high variable delivery time causes stockout situations for items and the other hand it causes the need for higher safety stock. Thus it is important to monitor deviation of delivery time. One part of the whole delivery time is order processing time in warehouse and order desk. Thus it is important to follow up these indicators as well.

By observation and data analysis CMI concept is not so widely and correct used in the subsidiary network. This means that there are done quite many purchase orders by manual. This indicates that item planning, product policy, and ERP transaction are not used right way and regularly. Manual working increases the need for resources and the other hand, it would be said as a waste of current resources. Thus, it is important to follow up CMI orders quantity of total orders.

As has been many times noted that logistics costs and inventory value are mostly trade-off to each other. Keeping low stock value might cause higher freight costs because there would be more stockout situations and rush orders are mandatory used. However, the idea is to find balance between them. Due to that, there is created KPIs for rush orders and freight costs. Especially, from inventory and item planning point of view rush orders would be reasonable to monitor by ABC-XYZ classes. One remarkable factor that affects to freight costs is chosen type of freight. Thus it would be valuable to follow up freight type ratio also.

Key performance indicators should be strongly involved in the company's management board agenda and systematically reviewed. This enables better management of global materials management and also provides deeper understood about it. In the next subsection is described the follow-up process for performance management.

4.3.2 Follow-up process for performance management

An essential thing in inventory management and its performance management is targets follow up. The follow-up means that targets are continuously monitored, and there is systematic way how to ensure target achieving. In previous sections are presented target setting model and KPIs for inventory management, in this subsection is described a new process model for performance follow-up.

Follow-up process will be organized quarterly in an internal meeting of subsidiary. The main idea of follow-up model is to follow up how subsidiary company has achieved the targets and reporting sub-results quarterly and analyzing deviations and reasons if targets are not achieved. Then there must be done some corrective actions how targets will be achieved and there should be stated responsibilities and deadlines for actions. The follow-up process model is described in Figure 54.

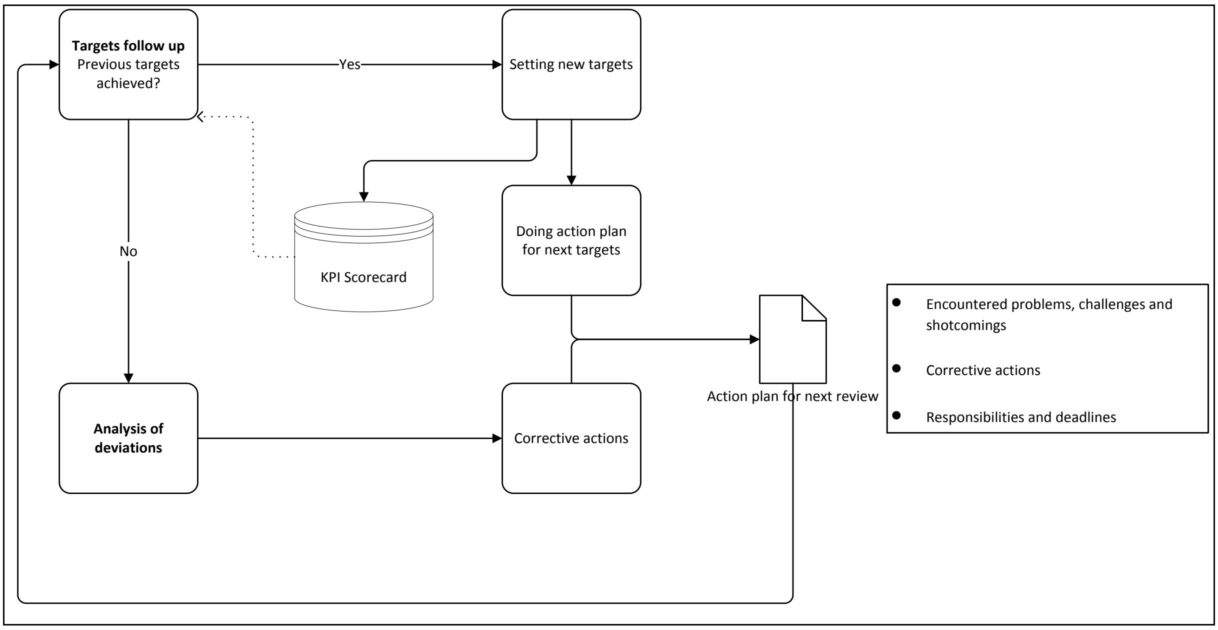

Figure 54 Performance follow-up model

In the next review meeting going to monitor the action plan which is done in the last time meeting. Action plan document follows along with follow-up until the targets are achieved. Once the targets are achieved, new targets can be set for the next period. However, targets are normally set for annually, thus new targets may not be necessary. Important thing in the whole follow-up process is reporting how targets are achieved in the subsidiary company and what have done to reach them. This process based follow-up model will enable the management and achievement of the targets in the group's global network.

4.4 Global materials management for spare parts

One of the biggest objectives of this thesis was how to avoid non-rotative stocks and ensure adequate service level for customers. In the bigger picture the purpose is to systemize inventory management in the global network; to improve information transparency, optimize total inventory value, keep items to stocked right places and increase inventory turnover while ensuring necessary service level for end customers. Inventory data analysis described that there are a lot of non-moving and overlapping inventories. Based on analyses and observations reasons for these phenomena are connected to a problem that there is not existing streamlined and unified materials management for global spare parts. Global inventory network does not perform as the case company has wanted. Thus, one of the findings was the need to create managing model for global spare part inventory management.

The objective of the global spare part materials management is to develop global inventory management to the same way and to harmonize practices what comes inventory management for spare parts network. On the other hand, there is a target to continue improvement of the CMI concept and improve management model and increase transparency in the global supply chain. In the previous subsection introduced performance management model which creates a base for global materials management. There also created regular target follow-up practice for global inventories. Previous there were not so clearly described routines and tasks what have to do and when. In addition, the purpose of the global materials management is to clarify operational routines and task during the year and make possible to lead global supply chain more efficiently. In addition, inventory management was not prioritized, and tasks are ignored partly due to lack of knowledge and unclearly described operational tasks, duties and practices.

Particularly in managing the global spare part network and inventory management it is important that transparency and target-oriented management model is mandatory. In the new approach model of spare parts inventory management, the communication is on the major role. In the future, there will be arranged regular materials management meeting with every subsidiary where is predetermined agenda. The objective of the meeting is to introduce current issues regarding inventory management, to review continuous improvement and give support to improve inventory management at overall. There will be checked previous meeting actions and review results of these. Global materials management meetings will be placed quarterly and there will be invited people from the parent company and the subsidiary which are responsible for inventory management and spare parts operations.

The purpose of the global materials management concept does not only use it management board level but especially in subsidiary's operational level. The idea is to expand target-oriented working and following up to operational level in the company. This consists regular arranged meeting where is following up improvement of CMI and inventory performance. The purpose of these meetings is taking focus to inventories and make actions what supposed to do to achieve better performance. The one main idea is to unify materials management meetings at the same level globally which helps to facilitate management and clarifies the goal of the whole network. The quarterly arranged internal meetings consist of the main agenda which basic structure is described in Figure 55.

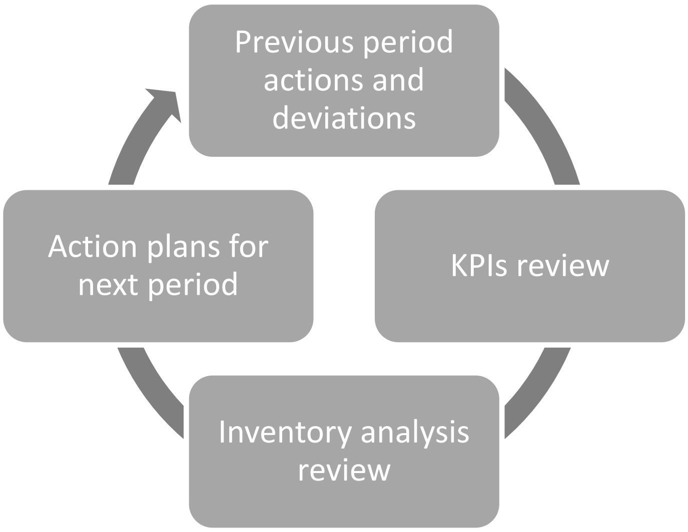

Figure 55 Main agenda and structure for internal meetings

The agenda of the meeting consists of reviewing actions what have done, KPIs reviewing and other analyses of inventory management. In addition, there will be done action plans for the next period. The idea is to report current situation to the central operation and increase communication.

5 CONCLUSIONS

Global industrial service business has been growing to significant role in the whole business, and many companies have begun to develop global service network and no cause. Service oriented business has created an entirely new income source for companies. Companies have started to provide solutions for the whole product life cycle. Particularly in machinery products entire life cycle service and maintenance is a necessity for productivity and efficiency. On the other hand, customers have begun paying more attention to the quality of aftersales, when making repurchase decisions. Industrial service business and customer service are strongly related to spare parts which are one of the major things when are maintaining machines during the life cycle. Thus customers are expecting good availability of spare parts. For companies desire to provide high service level may often cause a large amount of tied capital to inventories especially in the field of spare parts which demand is uncertainty and intermittent. Due to this reason companies have started to develop their spare parts inventory management to optimize inventory value while keeping high service level.

Grown, overlapped, duplicated and non-moving inventories have been a problem in the case company due to the business growth, product development changes, company's global expansion and the lack of inventory management. These phenomena of spare parts inventories have affected for one's part to negatively developed capital turnover of the case company. Due to this reason is started a development project which aims to find a solution to these challenges.

The main goal of the study was to create global materials management for spare part inventories by developing and streamlining current policies in order to the case company could optimize the invested capital in spare part inventories while keeping sufficient high service level and customer satisfaction.

The research problem resolved by answering the research question:

- How could global spare part inventory management of case company group be streamlined and unified and avoid overlapping and slow-moving inventories?

The study was done as action-oriented research, which had characteristics of a case study. The research was carried out using both a qualitative and quantitative methods. In order to meet the objective of the study, the study was divided into theoretical and empirical research stage. In theoretical stage was done a broad review of the research field, which provided the necessary information, research tools and methods from the field of study. As a result of theoretical findings was created a framework of study for an empirical approach. This framework for current state analysis included what should be examined, what techniques and tools are needed to analyze current phase and create solutions based on these. Based on the framework started empirical phase where information was collected by interviewing personnel and observing widely in the case company and analyzing data from information systems and documents.

Based on academic literature review and in the case company carried out empirical phase was observed significant potential to develop global materials and inventory management. In the study was noted that the main problem was a lack of performance management in global inventory management. There was not process-based target setting model for inventories neither systematical target follow-up model for performance management. In additional, the base of performance management, key performance indicators were not created. From item planning point of view items classification method was single criteria method which is too simplistic to classify items properly to homogenous classes, and analyze and control them. In addition, there observed that non-moving and slow-moving spare parts return policy was not sufficiently efficient to avoid bullwhip effect and dead stock in global inventories.

As a result of the thesis is created new operation model for global spare parts inventory management. The new model enables more efficient inventory management in global multi-echelon inventory system. It also improves transparency and collaboration between operations and simplifies management of subsidiary network from a working capital management point of view. The global materials management model includes new target setting model for inventory management and its continuous follow-up practice. The purpose of the new operational model is to streamline inventory and performance management. In additional, the model increase consistent and target-oriented management in the global network. There was created follow-up model for targets reviewing and achieving. A significant part of performance management and targets setting are useful and reliable key performance indicators. KPIs were determined and created taking into account company's needs and special features of the supply chain.

The global materials management model is not only operational model consisting target setting and regular follow-up processes. It also consists of regularly arranged meetings with basic and predetermined agenda. The purpose of materials management meetings is to increase transparency and information flow inside the subsidiary and the whole company group and unify management of the case company group. Subsidiaries meetings will be arranged in every month where are reviewing the current state of inventory management. It consists of previous actions evaluating, KPI reviewing, inventory analyzing and next actions to achieve KPI targets. The objective of the global materials management is that every subsidiary reports concisely current state of inventory management, performance of inventory management and actions for next period.

In this study was observed that the case company has been using ABC classification to classify and analyze items. ABC classification is commonly known classification method but academic literature proposes to use the supplementary method in the classification. The purpose of classification is to classify items to homogenous classes to handle and plan items more accurate depending on demand pattern. Multi-criteria classification makes possible to do planning more accurately and efficiently. One result of the thesis was the new classification model for spare parts. The new combined ABC and XYZ classification method classifies items by demand volume and frequency. ABC classification is based on the cost of goods sold value and XYZ classification on items transaction frequency. There are 18 categories in total where 12 classes for stocked items and six classes for non-stockable items. In the new classification model service level targets can be set more accurately for each class. In addition to non-stockable items there is created developed parts return policy for non-moving and slow-moving items. The new policy accelerates and enhances the return of non-moving items to the distribution center. Parts return proposals are formed automatically for every site quarterly. Material planning system has the main rules for determining parts returns, and proposals will be created automatically. Thus, resources will be released from manual working. The main advantage of the new continuous parts return policy is a more continuous material flow of non-moving items from service sites to the distribution center. It provides better inventory turnover at local sites and decrease bullwhip effect and overlapping stock value in global inventory network.

5.1 Assessment of the study

Based on broadly done current situation analysis the results were able to answer the research question and problem of the study. Results are done by understanding the case company environment and they are created to fit the case company’s operations. The solutions take into account the needs of the company and on the other hand, the constraints. Thus, usefulness and usability of the results can be considered for the case company.

This study is done by quantitative and qualitative methods, so main results and findings based on widely done analysis of current state problems and challenges. In addition, analyses are done using both methods in two subsidiary company and in the parent company. Thus, this increases the validation of the results and give reliable for the solutions to solve the research problem at the case company group level. Extensive interviews with the different functions of the case company created a reliable picture of the current state and the challenges it faces in the big picture. Also, data analyzing is done for five warehouse locations, and its give reliable the whole network problems and findings. However, the solutions were such that their testing on the project schedule was not possible. Nonetheless, the solutions have been made by the analysis, according to which was the main problem of study, they will be resolved with the results. The biggest challenge can be seen in the implementation of a new operational model into the global environment. During the implementation phase, it is important to remember uniform and clear communication, why change is needed and what will be achieved. Equally important is the development of people's competencies by constantly training and involving the organization to continuous improvement of the solutions.

Although the objective of the study was to solve the research problem, the study provided new reliable information of case company’s current situations and problems which are affected indirectly to the global spare parts inventory management. In addition, the study increased knowledge of the inventory management overall in the case company. Thus, this study opened and provided the beginning of the continuous improvement.

Although the results of the study have arisen in the case company and findings and results are company and case-specific, they can be utilized in other cases and studies. Nevertheless, it is extremely important to study the company's inventory management structure and understand its requirements and constraints. Thus, the results and solutions must be evaluated critically in the further studies, because business environment, inventory management system and common management system can vary a lot from the case company of the study.

5.2 Recommendations for further studies

This study offers possibilities for further studies in the case company. One of the future research question could be how inventory management, demand forecasting, and product life cycle management are integrated into the case company's business planning model. Successful business planning model including these aspects would provide a better starting point for strategic planning and especially better network planning in the future. It would make possible more efficient and profitable business for the case company. This study raised the need for spare parts demand forecasting. Successful demand forecasting would make inventory management more efficient and improve the availability of spare parts. In addition, the forecasts could provide more reliable and transparent information to suppliers, making possible to prepare future demand. There is available demand forecasting software which calculating future demand based on historical data. System evaluates demand pattern from the past and chooses the best forecasting method, in other words, the method is chosen by which has given the lowest forecasting error. Forecasting with demand data is the first step when developing demand forecasting. In addition, there should estimate demand with the sales experts. Combining methods are useful way to accurate demand forecasting and develop efficient supply chain.

Another major future subject of study is related to global logistics and direct material deliveries from a supplier directly to a branch warehouse. It would be necessary to study the benefits of the direct deliveries and how the direct deliveries should be managed in the global supply chain. Significant benefits of the direct deliveries could be improved lead time and reduced inventory levels in the distribution center. Especially because of the location of the distribution center, delivery time could be significantly affected by direct deliveries in urgent delivery cases. Direct deliveries could reduce costs with regarding freight costs and warehousing costs. In addition, direct deliveries would release storage space.

This study exposed the need to develop product life cycle management from the supply chain point of view. Continuous product development is seen challenging because there are a lot of product structure changes and new items are constantly designing. Thus, it is challenging to managing an increasing number of items. Hence, improving items replacement should be taken into consideration in the further studies. There should be done a new process model that mentions how to ensure that product development would be done more efficient taking into account the whole chain from the product design to the global inventory management. Thus, waste and excess can be minimized more effective way.

As the study noted, it is important to control inventories with ensuring availability of the spare parts. In spare parts inventory management, it is necessary to avoid stockouts, especially to ensure availability of critical spare parts. Thus, a systematic evaluation method should be created to identify critical items. This enables effective controlling for the critical items and provide more efficient stocking decision-making. In addition, review practices should be created to adjust and update criticality of the items during the product life cycle. On the other hand, spare parts recommendations process should improve that spare parts recommendations are up to date when demand data is already available. At present, spare parts recommendations cause overlapping and non-moving stocks, especially when recommendations are not automatically updated.

When the case company's spare parts demand and volume is growing it could be sensible to investigate the current inventory network structure. It would be reasonable to study the establishment of another distribution center for example to Americas to improve delivery times and decreasing freight costs between the central warehouse and North- and South-America.

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