Inventory Management from an aftermarket perspective

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ABSTRACT

This master thesis has been written on behalf of ABB Operation Center SE in Västerås. It is the last step of the master program in engineering - Innovation, Production and Logistics, at Mälardalen University, Eskilstuna.

ABB is an industrial company and a global leader in power and automation technologies and the role of ABB Operation Center is to provide aftermarket products and services all over the world. They offer spare parts, reparations, upgrades and exchange units for a large part of the products that ABB have.

With an overall knowledge and experience they provide solutions with availability and speed as their catchwords. Together with other ABB units and customers they develop the future aftermarket concept for industries all over the world. This is not an easy task since they handle articles that have a large range and the demand for service is high but the volumes are small and uncertain.

The purpose of this thesis is to find a strategy, or several strategies, in order to improve an inventory management that handles aftermarket articles. These strategies are built on four research questions.

In this thesis the authors, that are master students at Mälardalen University, have come up with suggestions for inventory management through four steps; planning, theoretical framework, benchmarking and analysis.

The research questions, structured in the planning step, are followed up in each chapter of the report. The data was collected and analyzed and the most useful information is presented in the theory, which is the base of this thesis, with focus on inventory management and aftermarket.

A benchmarking has also been done at four other companies that handle aftermarket. Here questions concerning the areas where ABB has issues were asked and answered. The information from the benchmarking together with the theoretical framework has formed to a suggestion of how ABB Operation Center SE should structure their work in order to manage their inventory in better way.
ACKNOWLEDGEMENT

This master thesis is the final part of the master program in engineering - Innovation, Production and Logistics, at Mälardalen University, Eskilstuna. It has been executed and written on behalf of ABB Operation Center SE in Västerås.

It has given us the knowledge and experience approaching inventory management issues and helped us understand the process, method and tools that can be applied when performing a scientific report.

We would like to thank Dennis Andersson at ABB Process Automation and Nils-Erik Jonsson at ABB Operation Center SE for the information and support. We would also like to thank Antti Salonen at Mälardalen University for all the support and encouragement and Stig- Arne Mattsson for the discussion and information.

Finally we would like to thank all involved in this master thesis, both the benchmarking companies and the employees at ABB Operation center who has given us their time and shared their information and knowledge with us.

Carolina Cardona and Lovisa Karlsson
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**DICTIONARY**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>ABB OC SE</strong></td>
<td>ABB Operation Center Sweden</td>
</tr>
<tr>
<td><strong>BD</strong></td>
<td>Business Development</td>
</tr>
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<td><strong>BI</strong></td>
<td>Business Items at Alfa Laval</td>
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<tr>
<td><strong>CLT</strong></td>
<td>Customer lead time</td>
</tr>
<tr>
<td><strong>CSN</strong></td>
<td>The warehouse for ABB OC SE that are handling the aftermarket articles</td>
</tr>
<tr>
<td><strong>DC</strong></td>
<td>Distribution Center</td>
</tr>
<tr>
<td><strong>EOQ</strong></td>
<td>Economic Order Quantity</td>
</tr>
<tr>
<td><strong>ERP-system</strong></td>
<td>Enterprise Resource Planning- System</td>
</tr>
<tr>
<td><strong>EWR</strong></td>
<td>Eldivision, Warranty and Repair</td>
</tr>
<tr>
<td><strong>EWS</strong></td>
<td>Eldivision, Warranty and Spares</td>
</tr>
<tr>
<td><strong>GDE</strong></td>
<td>Geotechnical Drilling Equipment</td>
</tr>
<tr>
<td><strong>HF</strong></td>
<td>High Frequency</td>
</tr>
<tr>
<td><strong>II</strong></td>
<td>Inventory Items</td>
</tr>
<tr>
<td><strong>Kanban</strong></td>
<td>Produce to order, no inventory</td>
</tr>
<tr>
<td><strong>LF</strong></td>
<td>Low Frequency</td>
</tr>
<tr>
<td><strong>LLT</strong></td>
<td>Logistic lead time</td>
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<tr>
<td><strong>LTC</strong></td>
<td>Least Total Cost</td>
</tr>
<tr>
<td><strong>MF</strong></td>
<td>Medium Frequency</td>
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<tr>
<td><strong>MRS</strong></td>
<td>Mining and Rock service</td>
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<tr>
<td><strong>NI</strong></td>
<td>Non-stocked Item at Alfa Laval</td>
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<tr>
<td><strong>OD</strong></td>
<td>Operational Development</td>
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<tr>
<td><strong>OI</strong></td>
<td>Order bound Items</td>
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<tr>
<td><strong>OTD</strong></td>
<td>On-time-delivery</td>
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<tr>
<td><strong>R&amp;D</strong></td>
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<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>SDE</td>
<td>Surface Drilling Equipment</td>
</tr>
<tr>
<td>SI</td>
<td>Stocked items at Alfa Laval</td>
</tr>
<tr>
<td>URE</td>
<td>Underground Rock Excavation</td>
</tr>
<tr>
<td><strong>Volvo LS DC</strong></td>
<td><strong>Volvo Group – Logistics Services DC</strong></td>
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1. **INTRODUCTION**

This report presents a master thesis performed in the academy of Innovation, Design and Technique at Mälardalen University in Eskilstuna on behalf of ABB Operation Center Sweden in Västerås. The master thesis is a part of an engineering degree within the program Innovation, Production and Logistics.

1.1. **BACKGROUND**

Logistic is something that every person is in contact with almost every day and something that is a big part of almost all organizations worldwide. With logistic comes several sub-areas, for example transport, production and aftermarket, all in which inventory is a key factor.

It is important to know that although inventory is important to have it still costs a lot of money. Therefore it is necessary to keep the inventory in balance and to only have what is absolutely necessary. Since it costs a lot of money, the company does not want to have components or articles in stock that has a very little or no turnover at all. Still the company does not want to be without a component or article when it is needed all of a sudden. This could cost the company even more in some cases and result in long lead times. In order to get this right, keep the costs as low as possible and offer short lead times to the customers, effective inventory management is the right area to work with. Models and methods to get the balance with inventory right are already available on the market and shows good results but the real problems occur when it comes to the aftermarket.

Companies want to decrease the cost of their inventory even for the aftermarket. The quality of products and components are increasing meaning that the product and components lifetime are getting longer. Due to this the guarantee-time will get longer and the company is forced to supply the costumers with spare parts for a much longer time. Because of this the pressure on the aftermarket will increase.

In order to manage the aftermarket there are several factors to take into account. There is a large product range and the demand on service is high but the volumes are very small and uncertain. Normally, in order to control the inventory, companies usually use a forecast based on history but when it comes to aftermarket this is difficult to do.

At ABB Operation Center, they manage the aftermarket for products which have the exact same properties; the components have a large range, the demand for service is high but the volumes are small and uncertain which means that they have difficulties when it comes to controlling their inventory.

1.2. **PROBLEM FORMULATION**

In order to stay on top of their game and still be the leaders within power and automation technologies, ABB also has to be a leader when it comes to the aftermarket and all that this includes, both products and services. A problem that almost every company stands before when it comes to the aftermarket is the fact that the volumes are very uncertain. When a customer needs something from the company, they want to be able to give it to them as fast as possible in order to keep them satisfied and happy. At the same time it costs to have articles in stock. This is where the company needs to find the right balance.

ABB Operation Center are working with these kind of issues all the time but when the company does the same thing day in and day out it can be difficult to find improvements. Therefore they need help to find solutions on how they should manage their inventory of aftermarket components in order to minimize the costs and satisfy their customers.
How does a company organize their work when the components have a large range, the demand for service is high but the volumes are small and uncertain?

1.3. AIM AND RESEARCH QUESTIONS
The aim of this thesis is to study and present proposals for solutions on how ABB Operation Center Sweden (ABB OC SE) can manage/control their inventory. The aim also includes to present strategies, so that ABB OC SE are able to reach a structured and standardized way of managing their aftermarket inventory. This is an important aspect when it comes to the aftermarket since the demand is very varied and it is hard to control the inventory in such a way that the company keep the costs down while meeting the customers demand, concerning lead times and on-time-delivery (OTD).

These are the research questions that concerns inventory management:

- How does a company decide if the items should be stocked or order bound?
- What systems are there to decide the order point?
- How does a company decide the order quantity?
- Dimension of safety stock

In order to manage and control the inventory completely there are two other aspects to examine; where should the warehouse be located and how does a company handle the scrapping process? The reason why these research questions are not included in this thesis is described in 1.4. Project Limitations.

1.4. PROJECT LIMITATIONS
The project will mainly focus on the purchase aspect of the process but in some ways other departments will also be included, such as order and quote.

Since where the warehouse location cannot be affected and since it is not relevant, that question will not be handled in this report. Due to the time issue there is no time to handle every question and because of this the decision is to not include the scrapping.

If time remains a case study on one- or a few components will be done where management solutions for specific components will be shown.
2. METHOD

There are several methods to use when performing a scientific research, in this case a master thesis. In this chapter the methods used in this specific thesis are described.

2.1. METHODOLOGY

A methodology works as a form of guideline in order to solve a problem. The methodology usually contains different steps such as phases, tasks, methods and techniques.

2.1.1. QUALITATIVE AND QUANTITATIVE METHOD

Qualitative and quantitative methods aim to the generation-, process- and analyze choices. Within the quantitative method the research includes measurements from data collections and statistics process- and analyzes methods. The qualitative method is about research form a data collection that focuses on the soft values, such as qualitative interviews and interpreted analysis. [Patel and Davidson, 2011]

2.1.1.1. Qualitative Method

The three phases

First comes the planning phase that has two important steps; the first one is to formulate a question. The second step is to formulate how the interview should be executed. After the planning phase the collection phase comes where the demand of expertise is needed when information should be found. The last phase is the analysis phase; this is where the collected information is analyzed and results with a theory chapter. [Hartman, 2004]

Ely (1993) describes five steps that should be performed in a qualitative method. Those steps are: the beginning (what is important in qualitative method), the implementation (how to use the tools in a qualitative way), the feeling (the individual aspect), the interpretation (the analysis) and reflect.

In the beginning it is important to find those questions that are interesting on a personal level and from this the research questions are formulated. That is a qualitative work, to base their research on something that is interesting on a personal level and then find the right research questions from that. One of the qualitative methods is that the research questions are developed under the study’s time. In a qualitative method there should be questions to answer before the study starts, they are often broad. The acceptance of the questions variability is both a problem and a positive factor in qualitative research. [Ely, 1993]

When it is time for the implementation phase it is time to start observe. The easiest way to observe is to collect fact with the ears. One of the first things to reflect over when it is time to observe is what kind of observer role that are suitable for the area should be taken. Should it be an active-, privileged- or restricted observer? The active observer has a work to perform after the research. The privileged observer is a person that can be trusted and finds it easy to collect information and the restricted observer (the most used) asks questions and builds a trust during the studies time. Which role should be chosen depends on the opportunities that the context allows. [Ely, 1993]

The feeling step is about all feelings that can occur within a person when a qualitative research is done. As a qualitative researcher the individual point of view is an important factor and this can be both positive and negative. It is common that the researcher experiences unexpected feelings, chaotic or disturbing. [Ely, 1993]
Interpretation or analyze is to find one or more ways to come up with the result. Before this step is reached some decisions about factual analysis have been done, many of the decisions are affected by the qualitative research that drives the study forward. Regardless which analyze method that is used it is important to clarify that a result should be reached through this study so that the reader will understand it early in the analyze part. [Ely, 1993]

The last step, the reflection step handles the experience that has occurred from the study. Help to analyze what new knowledge is found and what to bring to future studies. [Ely, 1993]

2.1.1.2. Quantitative Method
Quantitative methods are very helpful when a structure should be reached in the data that are collected. It is not only for an individual overview of what has happen but it is also helpful for the ones who will take part of the information. The information could be complex and the quantitative methods help to get the complex information understandable in an efficient way. To find a structure in the information and to analyze the connection between different phenomena can be difficult and take a lot of time. The questions that are formulated from the beginning usually change under the works progress, they are rejected, modified and get further developed. If methods are used to describe phenomenon it will lead to a more simple comparison between other studies. Time and space will be saved and the availability for interested readers increases when obvious information need to be described so it can focus more on the special, current questions. [Eggeby and Söderberg, 1999]

According to Eggeby and Söderberg (1999) there are four steps to go through in order to achieve the best result. The first step is to look self, a first analyze. When the data is collected a first overview should be done. An overview in order to create an overview picture of the information, investigate if the information is symmetrical or imbalanced. It is about to create a perception about the information’s spread. The second step is to analyze with quantitative methods. When the material has been analyzed in the first step it is appropriate to analyze the information with a statistical process, in which way depends on several factors. How the questions is formulated is one of the factors, if the questions is how big or how many tables, measures of central tendency and dispersion measures can be an important aspect. If the research questions handle questions such as how do factor A affect factor B is a relationship analysis the right method. If a study is done where a comparison should be done of a work that was done in another place or time, it is appropriate to make the same calculation in order to reach the optimal comparison of the situation. The third step is to interpret the result. When the analyses are done, the overview and the quantitative, it is time to interpret the result. It is not the readers’ task to decide what is much or little. The interpretations should be reasonable and answer the research questions. It is important to compare the result with others and by that be able to discuss similarities and differences of the results. The fourth and last step is to report and present the result. They should be presented in a credible and fair way and it should look good.

2.2. Work process
A work process refers to the way that the work or study has been done. The work process can be different depending on what the study contains.

The goal is to, at the end of this project, present a number of proposal solutions that could help ABB OC SE in their management work and in order to do so the work will be in three steps:

- What does the theory say?
• How do other industrial companies work with these issues?
• How should ABB OC SE work?

2.2.1. PLANNING ACCORDING TO DMAIC
In order to get a result oriented framework DMAIC can be used which is a systematic and fact-based approach. DMAIC stand for define (identify, prioritizing and selection of project), measure (key processes, parameters and the performance), analyze (identify key causes and processes), improve (by chancing the process and improvement performance) and control (sustaining) and it refers to a lifecycle that has a Six Sigma approach, to improve the processes. [Sokovic, Pavletic and Pipan, 2010]

The process starts with defining what the problem is and why it should be solved. In order to do so; purpose, problem and questions are helpful tools. The problem statements are usually not determined to 100% when the work starts, when information are gathered some other problems can occur and the purpose will then change. A change of the problem statement can depend on limitations that occur during the information gathering process. [Ejvegård, 2003]

If the process cannot be defined it is not possible to measure it. This means that if the process cannot be defined it would not be possible to use DMAIC in order to develop the process and improve it. The best result that is achieved from DMAIC is when the process is flexible and it is possible to eliminate the unnecessary steps. [Sokovic, Pavletic and Pipan, 2010]

2.2.2. VISUALIZED WORK PROCESS
From the DMAIC method a new method has been developed in order to optimize this projects planning. The method is visually shown below in figure 1.

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Figure 1 The developed method of the work process based on DMAIC

Define: Planning and Preparation and Current State Analyze falls below the defining. In the Planning and preparation phase a plan of the project is designed. Questions that should be answered are formulated and the need for benchmarking is realized and planned. Current State Analyze handles how it is today, what problems exist and what is there to improve. In this phase it is important to understand these questions in order to develop the research
questions from the previous step, Planning and Preparation, so they will agree with the problem.

**Measure:** In order to answer the research questions, information has been collected in four different ways. The first is Theory, what has already been written about the subject? Interviews of the employees at ABB OC SE have been contributed to understand the situation, a deeper understanding than the Current State Analyze is reached. Sometimes the theory covers methods that are not used of companies, so in this stage it is also necessary to do a benchmarking in order to see which methods that companies use. The last factor in this step is the documentation, while the information gathering is done, it is recommended to make documentation in order to remember everything.

**Analyze:** In the DMAICs Analyze it is the Analyze step in the new process as well. Here is the theory compared to the benchmarking and a few Solution Proposals is developed.

**Improve:** The proposals that have been developed are thoroughly checked and improved if needed.

**Control:** The final proposals are in the control-phase controlled an extra time.

2.3. **DATA COLLECTION**

Preparing and collecting information is called data collection. The data is collected in order to provide information regarding a specific topic.

2.3.1. **LITERATURE STUDY**

A scientific work should be factual, objective and balanced. Factual means that the information is true, this means that the information should be checked to see if it is correct. One way to do this is to go to the primary source and control because it is likely that the secondary sources are incorrect. Reliable sources in addition to the primary sources are scientific works, doctoral dissertations and other secondary sources where the author has been thoroughly with the control of their sources. Objectivity is something to strive for especially if the work is done of a scientist but it is not always easy. It is difficult to discover the prejudices and preconceptions that a company has. When it is time for information gathering, objectivity should be taken into account, this because of which information should be used and this can be decided from the factors prejudices and preconceptions. Both fact and objectivity are included in balance, which is the third factor in a scientific work. An analytic distance to the subject is a factor to strive for within the balance. [Ejvegård, 2003]

Literature study can also be called literature search, the literature handle in research way everything that have been printed, books, articles, reports and essays. A school library’s databases is one alternative to litterateur studies, in order to find the right information keywords are typed in. The persons writing the literature, no matter what kind of literature, needs to know what the keywords are in order to optimize the search. The keywords in the searching can be useful later when it is time to write keywords in the literature. [Ejvegård, 2003]

2.3.2. **BENCHMARKING**

A case study can be done more or less ambitious and detailed and because of this it is useful in most scientific work. The purpose of a case study is to describe a specific case and not a whole process but it is important to know that there is a downside with this method. The downside is; when an analysis of the case study are being made it can be difficult, this
because of the fact that the whole process is not described, which can lead to incorrect conclusions. [Ejvegård, 2003]

**What is benchmarking?**
The definition of benchmarking is somewhat varied. The pioneer of this technique’s application is Xerox Corporation, which would define it as: “The search for industry best practices which lead to superior performance”. Benchmarking is used to mark up certain parameters, products and strategies to create a perspective of the actual performance of the industry. This helps the company to compare their different strengths and weaknesses to the leaders of their industry and from there develop adjustment and improvement. The measuring and improving are an ongoing process. “There are no limitations on the search; the more creative the thinking the greater the potential reward”. To monitor the in-house outputs thoroughly is the only way to create the possibility to recognize and filter the differences or innovations that are found in ‘best practice’ companies. [Codling, 1995]

The benchmarking is divided in four different stages:
- Planning
- Analysis
- Action
- Review

Each stage must be carried out with precision but to eliminate wasting time in the later stages more time should be spent on the planning process. In its own right the review is also a very necessary stage due to the interweaving through the planning-, analysis- and action phases. [Codling, 1995]

The phenomenon of benchmarking can be divided into three types or perspectives:
- Internal
- External
- Best practice

To quickly describe them it can be said that internal refers to the partners within the company, or division. They may be based at the same, or at a different location. For example, if the company has identified a process that deals with customer complaints they could compare the practice of this process across different departments within the company. [Codling, 1995]

The external benchmarking handles benchmarking among external partners within the group, for example in an international company. These may be totally different companies within different industries. The fact that they produce different products can be an advantage rather than a disadvantage, since it is possible to learn many new things. [Codling, 1995]

Benchmarking against best practice means that the company seeks out the leader in the process that may be critical to the business success. The problem is not to find the best; it is to define what it means in terms of the process that being examined. [Codling, 1995]

2.3.3. **Interviews**
The most common in research is to do interviews, one at the time. Interviews take time both at the empirical and analyze step so it is important to choose which should be interviewed carefully. An interview mostly occurs when a person asks questions to someone else. In order to be able to retell the interview notes should be taken, it is also possible to record the
interview. Unfortunate interviews that should be recorded can be inhibitory for some people. In some case the person can say that they do not want to be recorded and that need to be respected. Studies have shown that even notes can be inhibitory but notes need to be taken. In order to let the person that is interview to feel as comfortable as possible keywords can be noted and right after the interview more detailed notes can be written. When the interview is done and the interviewer has written a first draft the person that were interviewed should be able to read through it and comment if something do not accordance to their answers. [Ejvegård, 2003]

A person is being interview because of the fact that someone wants to learn something that the interviewed person has the knowledge about, which leads to this person being able to answer the questions. In order to reach a quantitative interview it is important to have a standard approach and a structure. If the interview has a standard, everyone who gets interviewed has the same based conditions, which leads to a more easily analyzed comparison. A structured interview controls how much restriction an answer has. [Hartman, 2004]

2.3.4. DOCUMENTATION

A documentation need to be done in a thesis work in order to pass, so that the examiner can follow all the steps that have been done. In the documentation it is important to give argument that the work have been done independently and creativity. [Nilsson, Olsson, Svensson and Lindgren-Sand, 2011]

In a documentation there should be several factors that are included, disposition, time plan, title, author indications, headlines, foreword, keywords, abstract, contents, introduction, theory, empiricism, analyze and closure. The two first factors (disposition and time plan) are only documented for the writers to this thesis own sake. Title, author indications, headlines, forewords, keywords, abstract and contents are the factors that helps describe the whole thesis work. The introduction gives a short introduction of the current state and why this thesis is done. Theory is based on what have already been written in the subject. In this theory part the writers have tried to use primary sources so they are validated. It was not possible in all cases so the secondary source have been used in those cases. Other companies than ABB have been interviewed and the author have taken for granted that the information provided by them is correct, no further evaluation of credibility of the information is made. The same is for the part about ABB. The companies’ websites have also been used in order to describe the companies. The analyze part is done of the theory and empiricism, the interpretation is done of the authors. The closure is the part where everything is tied together. [Ejvegård, 2003]

2.4. ANALYSIS

The analytic induction is characterized by three steps, which a company goes through in order to analyze the collected data to reach a valid theory. These steps could be described as following:

First there is the planning step and this step contains two important operations. The first one is to formulate a question that the research should answer and the other operation is to design the research, decide how to answer the formulated question. When the question has been formulated and the knowledge of how the work should be executed exist in order to answer the question, the second step is initiated, the gathering of data. This is something that requires good judgment and knowledge in order to see what is important and valid and what is not. Finally there are the analyze step where the collected data is analyzed and a valid theory is emerging. [Hartman, 2004]
When it is time to analyze it means that a result has incurred but is not found yet. In order to find it, it is possible to take help from two useful steps. The first one is to describe the collected information in a way that makes it easier to analyze, one way to do this is to organize all the information. The second step is to analyze the questions of the problem solution and where these are presented. [Hartman, 2004]

A discussion around the result can in some cases be executed through the work but it usually happen when the theory and empiricism are finished. In the analysis the writer’s opinion are expressed. The analysis can sometimes end with suggestions to further research around the problem. [Ejvegård, 2003]

2.5. RELIABILITY AND VALIDITY
In order to control if the collected data is true and valid, certain methods are to be used.

2.5.1. RELIABILITY
The reliability indicates the accuracy within a tool. If a tool is accurate, the results should be the same every time something is measured. As an example, if a length should be measured and the measuring tape that is available is a rubber band. If it shows that it is difficult to get the same result on the measuring tape of rubber it shows that this measurement is not reliable. When a scientist takes measurements they often develop a tool themselves. If a person should make the same measurement as the scientist they need to be aware of the fact that the tool that has been used in the first place may be different from his own, which can lead different results. [Ejvegård, 2003]

In the evaluation of the problems it is recommended to use reliability, this in order to get a result that is correct. [Ejvegård, 2003] There are reliabilities measurements that decide how stable the tools are. These measurements are expressed in connections and are described in statistical books. When a measure cannot be obtained the reliability will ensure the accuracy of the survey in another way. If interviews or observations are used in the survey the reliability depends on the interviewer’s ability to interpret the interview. The interviewer make assessment when they interpret the received answers, it is possible that error of the assessment happen. The condition for good reliability is that the interviewer is trained, if the interviewer is trained and the interview is structured the reliability will get higher. [Patel and Davidson, 2011]

2.5.2. VALIDITY
Accurate measurements and metrics are factors that are the base for a measuring without any problems. It is important that the right parameters are measured in order to get a result that is helpful when an analysis is done. It is also important to know what the measurement stands for and how they should be used. [Ejvegård, 2003]

If clear measurements and metrics are available there should be no problems. If a measurement of the population in a country should be done, there are different ways to do so. For example, it is possible to count the people in the country, the people that are permanently living in the country or the number of citizens. These methods differ from each other but each method is valid since they measure what they purports to measure. [Ejvegård, 2003]

It is important to know what the measurement is used for and to then use it consistently. It cannot take statistics from different sources and use it without knowing how this statistic has been developed since it can differ a lot. Someone who has developed statistics for a country’s surface may have counted the surface without lakes and seas, while someone else has
included lakes and seas. It is then not valid to compare these statistics from different sources with each other. [Ejvegård, 2003]
3. Theory

This chapter will include the theoretical parts that lie as a foundation for this thesis. The different methods used to manage the inventory from an aftermarket perspective will be presented.

Introduction Inventory Management

The inventory management is more in focus today, which depends on the competitiveness. A company needs to control their inventory in order to reduce their cost and satisfy the customers. Managing the income and costs can be seen as an inventory difficulty. This can be solved through different methods. [Koumanakos, 2008]

Traditionally, the management in inventory is focusing on the production and procurement in order to solve the difficulty. Today there are more methods to choose from in order to manage the inventory, these methods are more focused on the management instead of the production. The inventory management is only one factor that affects the performance in a company, even so it is an important factor. [Koumanakos, 2008]

Minimizing the cost or maximize the profit is the two most common goals that an inventory management try to reach. It is necessary to find methods that make it possible to reach the goals and at the same time satisfy the customer’s demand. [Koumanakos, 2008]

3.1. Logistic

The most important aspect in order to deliver products when they are needed and to an optimal price, is to control a company’s material flows in an effective way. Logistics is about controlling the material flows together with the activities and systems that are associated with this. [Lumsden, 2012]

Effective material flow is something that has always existed but the interest to work with it has changed over time and is depended on what the area of usage is. Looking at the industry, the context can be seen as a significance of effective material flow that has increased a lot since the Second World War. This is because of the fact that this resulted in an increased variation flora and complexity, resulting in problems for the management by for example high handling- and inventory costs and poor delivery service. [Lumsden, 2012]

The view on logistics has also changed over time. In the 80´s logistics was primarily directed toward capital, while it later was time that was the focus. In the most recent years the focus has changed even more and what is seen as the most important aspect now is to fulfill the customers’ needs and demands. These other aspects have come to the surface, such as quality and information, when the company realized how important it is in order to have an effective material flow. Even change-processes are something that is starting to be discussed, it is important to know WHAT a company needs to do but also HOW to do it. [Lumsden, 2012]

Thus, it can be said that logistics is the study of effective material flows. The word includes both strategic and operational aspects, strategic in the sense of helping the company that by having a material oriented view reaches a higher external efficiency, doing the right things. The operational aspects means correspondingly that through a number of techniques to obtain a high internal efficiency, doing things right. [Lumsden, 2012]

The concept “logistics” is defined different in different parts of the world. Scandinavia sees logistics as a synonym to material administration. In the USA however logistics is associated with physical distribution, while the term “business logistics” is much more alike the Scandinavia´s interpretation. A more general definition could be:
“The approach and principles according to which we strive to make our plans, developments, coordinate, organize, steer and control the material flow from raw material supplier to final consumer” [Lumsden, 2012, p. 255]

or

“Logistic covers the activities that has to do with obtaining the right product or service at the right place, at the time and in the right quality to the optimal price” [Lumsden, 2012, p.255]

It is important to take the whole flow into account, not just the activities that take place inside the company or at only one department. The company needs to see the whole picture and include all activities and aspects between supplier, company and customer. [Lumsden, 2012]

Figure 2 illustrates this in a simplified way:

![Figure 2](Lumsden, 2012)

3.2. WHAT IS AFTERMARKET?

Before, the local distribution slowed the possibility to create an effective distribution of the aftermarket products. The reason for this was that the collaboration between the different service locations, which were small and scattered, did not exist. [Andersson, 1988]

Increased quality affects the aftermarket in different ways, one is that the demand of service and maintenance are decreased. Another reason is that if the quality is higher the product life will be longer, which leads to a longer time of repurchase and guaranty. [Andersson, 1988]

Some companies are outsourcing the aftermarket. This because they think that aftermarket is something that is needed but not something that brings a lot value for them as a company. There are downsides with this action, one is to control that every outsourcing distributor has the right quality-aspects on their components in order to match the company’s products. [Andersson, 1988]

The competition on the aftermarket will grow in the coming years, this depends on the fact that other manufactures have reached this market. This comes from the rising awareness among other manufactures; they are new on the market and have another kind of understanding for the importance of service and maintenance. The customer’s awareness of the importance of service, maintenance and the total economy are also increasing which leads to the fact that new manufactures, which takes these aspects into account, are competitive at the aftermarket. [Andersson, 1988]

In order to manage the inventory it is helpful to have good market knowledge, which is reachable if a close contact with the costumers exists. Then it is possible to know the demand of a component before they make an order and can regulate the amount of components in
stock. With good relations with the customers it is possible to arrange prevention work. [Andersson, 1988]

Good relations with the customers are important but it is equally important to have a good relation with the suppliers. If the collaboration is positive the company can reach advantageous contract with their suppliers and the flexibility will grow. [Andersson, 1988]

Companies can be divided into four groups that depend on how they manage the aftermarket. These four groups are different interpretations that companies have that handle the aftermarket:

- As a necessary evil
- Good but think of the aftermarket as a separate part from the other departments
- Same as the group above but in this case they have integrated the aftermarket in the other departments
- As their primary market

[Andersson, 1988]

3.2.1. PROBLEMS WITHIN AFTERMARKET

Both internal and external problems exist within the aftermarket part of organizations. Within the internal problems there is a trend that shows some lack of commitment from the management when it comes to questions regarding the aftermarket. The only commitment there is stays with saying that “yes, the aftermarket is important for the company”. After this all the responsibility is transferred to strategic planning and the department that directly handles the aftermarket. In many companies there is a lack in representation from the aftermarket department in the company’s strategic discussions. This can lead to setbacks for both the service department and the management when they have to revise strategic plans due to unforeseen events on the aftermarket. [Andersson, 1988]

So it can be said that the service department is struggling with status problems within the company. This depends on the lack of internal marketing, which could lift the service department status. This lack of status leads to less recourses when it comes to competence development among employees and development for service routines. All the organizational changes are made due to primary sales instead of partly adapt it to the customers need of service and to the market of aftermarket handling. [Andersson, 1988]

Another common problem among organizations is the issue of how to organize, plan and conduct new product sales and service relative to each other; how to avoid overlaps and contradictions between these two. How can interaction be achieved? [Andersson, 1988]

This can also be a problem if a company sees to the international perspective, when establishment on new markets occurs, the aftermarket often gets forgotten or set aside. This could lead to difficulties that might take years to get rid of. Often the responsibility for aftermarket is put on each individual subsidiary or dealer without any collaboration with the main organization or other subsidiaries and dealers. Despite these deficiencies, the conditions for export companies to take advantage of the possibilities that the aftermarket has to offer are there. The knowledge and experiences are there, what is lacking is the insight that the aftermarket, with large elements of services, may require a different approach and another company culture for export of products than traditional export. [Andersson, 1988]
If the aftermarket should get right attention they should get the possibility to get the resources required in order to conduct their own business- and market development. At the export market, aftermarket is a relatively little exploited resource but it is the aftermarket that offers possibilities that could strengthen customer relations, both old and new ones. These unused resources exists both internally within the company as well as externally at customers and others. [Andersson, 1988]

Other problems are for example:

- Distribution of aftermarket products and services
- Selecting staff
- Strategies for pricing and market segmentation
- Knowledge development within the area
- Development of information systems and routines

Many organizations have, despite these problems, discovered more short-term, revenue related profits that the aftermarket can stand for and the long-term competitive advantages that efforts on the aftermarket organization can cause. This shows that the interest for aftermarket has increased over the years and for many organizations it has become an important complement to primary sales and a starting point for business development. [Andersson, 1988]

Traditionally companies have been focusing and devoted substantial resources to product development in order to improve the quality and strengthen other selling properties of the product. What is important to know here is that quality is not only created due to a good product. Even a flawless product with a nice design could be wrong if it does not match the customers view on what the quality should include, or if a good after sales service is missing. An excellent customer service can rarely compensate for a bad product; while a bad customer service quickly can slander whichever advantages the business have to be able to deliver high-class products. [Andersson, 1988]

Many customers that buy a product see it as an investment and have expectations beyond the actual product. These expectations can vary, depending on the customers- and the organizations market. Some customers may need help with installation, quick deliveries of spare parts, preventive maintenance or training for the users of the product. It is important for the manufacturing company to know what the expectations the customers have, even if they do not control the aftermarket themselves but leaves that part for other actors. [Andersson, 1988]

One of the greatest slogans nowadays is the part where long-term relations between seller and buyer are very important. It is good for every company to know that if they have a good working aftermarket they probably will have good relations with their customers. [Andersson, 1988]

3.2.2. SPARE PARTS MANAGEMENT

**Large amounts of money bound in inventory:** By using independent subdivisions the inventory is unnecessarily high which lead to unwanted costs. If that is combined with a very low turnover the combination is not good. [Andersson, 1988]

**New plans for the spare parts management:** Liquidation of the main inventory (partly) and the independent subdivisions inventory will be initiated. This will decrease costs and will indicate that the action are decreased with one intermediary. [Andersson, 1988]
Other important questions: Standardizations of price and commission system within the spare parts distribution should be executed in order to reach a more effective result. [Andersson, 1988]

3.3. INVENTORY MANAGEMENT
Both inventory- and customers order production exists; this is about production but can be implemented on the aftermarket as well. Inventory production means that the production is based on a forecast of how many products expected to sale. The volume affects how many products that are produced and how long it will take. Inventory production can be used both on continuous- and series production. Customer orders production depends on the orders from the customers. The production starts when an order is decided. [Hågeryd, Björklund and Lenner, 2002]

In the 1980’s the Just- in- time philosophy were introduced in Sweden and since then the existence of inventory were discussed, some thought that inventory only were a load. If an inventory only is a burden why do mostly companies still have them. Toyota knows that the inventory is not a waste but they think that unnecessary inventory is waste. It is not possible to eliminate a whole inventory and it is not suitable. Inventory control is about receiving a balance between the inventory size and the utility value, not to reduce inventory. The inventory is an asset to the company and creates value by decrease the costs and increases the revenues. [Mattsson, 2012]

The utility values that the inventory brings are, decreased transaction costs (the costs that are associated with a procurement process, purchased materials, costs of ordering, delivery control, transportation, receiving, quality and quantity control, placing in storage, processing of supplier invoices and payment of supplier invoices), increase delivery capacity (how short the delivery time can be, how safe the promised delivery time are and in which extent is possible to deliver direct from inventory ) and improve capacity utilization (how to use the existing resources). [Mattsson, 2012]

In order to clarify how these values affect the inventory it can be divided into three different types, current inventory, safety inventory and smoothing inventory. The current inventory is the first type and is based on the size of the order quantities and is necessary in order to receive the delivery capacity and satisfy the customer with a short delivery time. The size of the order quantities is also affecting a company’s delivery capacity, in regard of service. If the order quantities is halved the risk for a lack is doubled which leads to that the service level decreases if the safety inventory is not increased. The order quantity is also affecting the transaction costs, if the order quantity is halved (and the current inventory) the orders, goods receiving, quantity and quality controls, inlays in stock and more invoices to manage and payments to perform will be double. [Mattsson, 2012]

The second type is the safety inventory, one of the utility values is the impact on the delivery capacity. Due to the variation of demand and the fact that forecasts never can be expected to be accurate a safety inventory is crucial in order to keep the service level and the delivery time. Another type of value is to reduce disorders within transportation. If it does not exist a safety inventory with time- or quantities buffers a disorder will occur because of the variations. The result of this is that the transportation resources get limited. Smoothing inventory is the third type that creates utility values. This inventory makes it possible to keep high capacity utilization even if the demand varies. [Mattsson, 2012]

An inventory consists of both necessary and unnecessary parts. The unnecessary inventory does not contribute to decrease the costs or increase the revenue so this should be reduced.
Cost will increase and the revenue decrease if the whole inventory is seen as an unnecessary inventory. [Mattsson, 2012]

**How to solve the variation problem**
Compared to a few years ago company’s ability to adapt to variations from customers- and market demand has increased. The requirement of a flexible material supply is increasing in order to reach a satisfied adaptability but there is a limit on how long it is possible to take the flexibility. There are a few different flexibility concepts that can be separated:

- Product flexibility – the ability to develop and adapt products after the markets need
- Product mix flexibility – the ability to make changes in the product mix in the production
- Volume flexibility – the ability to produce and deliver as demand changes
- Delivery flexibility – the ability to change delivery time and products within the delivery time

[Mattsson, 2010b]

To have products in inventory leads to a higher capital and at the same time it is possible that it is wrong products that are in inventory, because of the uncertain prognosis. One way to solve this problem is to increase the predictability. It is know that if the variations in demand are known at the right time it is easier to predict and adapt the inventory. If the forecast accuracy is improved the predictability is increasing. [Mattsson, 2010b]

Another way to increase the predictability is to forward information of the real consumption in the retail trail down through the material flow chains. If that happen, the units that are material supported is able to build their plan on information that is real from a demand perspective. This can happen without any time delay. [Mattsson, 2010b]

The last solution to the problem is to make the variations in demand more predictable. To reach what a company should make the modern information technology is more efficient. If they do that, they will get a better opportunity to adapt variations that are coming. [Mattsson, 2010b]

3.3.1. *Methods to decide whether to have inventory- or order bound items*

A company can either have articles in inventory or place their own order when they receive an order from the customer, order bound articles. In this section different methods to decide what articles should be in inventory or order bound are described.

3.3.1.1. **ABC Analysis**

An old way to calculate the workload and control parameters within the material management is to use volume values. With this method components are divided into groups and classifications depending on the volume values, the components value times an annual consumption or if the volume value is expressed in another way that also is useful. Different strategies are affecting different groups. In most cases it is three groups that are developed, which are called A, B and C and those groups has given this method the name ABC analysis. The components that have a high volume value are placed in group A, the articles with medium volume value exist in group B and in group C are the articles with a low volume value. This method is based on the minatory law, which also can be called 80-20 rule. It is Vilfredo Pareto that has developed this principle and it goes:
“In every series of elements a small number of elements always corresponds to a large portion of the power” [Mattsson, 2003, p.1]

ABC analysis and other strategies for different groups of articles are a traditional approach to get knowledge around the components which then can lead to a more efficient way to control the flow of material and resources. This was especially important when the planning efforts were made manual. The usage of 80-20 rule decreased when the Enterprise Resources Planning- system (ERP- system) increased. The reason for it seemed to be that if a computer was used, the concerns of where to prioritize the resources were not required in the same scale as before. In one perspective this reasoning is correct but it is not only ERP- systems that have the ability to calculate effective material flow. Manual work is still necessary because when the results of the calculations are done and the decisions of what should be done have been taken it will be implemented in practice. ABC analysis and ERP- system do not replace each other. If ERP- system is used for the logistics it does not mean that ABC analysis should stop be used. [Mattsson, 2003]

As said previously the ABC analysis are often divided after the volume value but this is not always the most suitable, in some cases it is even wrong. This can depend on that Pareto’s minority law has been interpreted wrong. His principle is about sorting important components from less important and to divide the resources on those parts that are significant instead of those how in compare are less significant. If a component has a high volume value it does not mean that the component is important. In some cases the groups dividing of volume values are right but in some cases there are not. [Mattsson, 2003]

In order to use the ABC analysis to the fully it is necessary to divide the group after the right criteria, which not always is volume value. A recommendation is to choose a value that affects a company’s improvement projects. If a company would like to improve the company’s profitability through selective targeted sales efforts, they should probably base their ABC analysis on contribution margin instead of the turnover which can be interpret as a more obvious choice. Recommended is to divide the components after a cause/ effect- relationship. If there exist a more complex cause/ effect- relationship than the margin and the turnover has it can be necessary to divide the components after more than one factor in order to reach a fairly dividing. [Mattsson, 2003]

It is nothing that says that a categorization should end with one level. If a company would like an effective categorization ABC analysis can be made on subgroups of the total selection of components. A categorization can be that starting material should not be in the same subgroup as finished products or purchased components with self-produced components. [Mattsson, 2003]

Categorizations of the components can be done in an effective way with today’s ERP- system. Generally, a categorization of the components does not need a manual effort and it is easy to implement. Even though it is economical to make the categorizations they should not be executed too often. On the contrary, it is desirable to have the components in the same ABC group under a longer period of time. If changes in the ABC categorization are done often there is a risk that the employees get confused and do not know which component that belongs to which group. If it happens there is a risk that the categorization is not used in sufficient extent. [Mattsson, 2003]
Outsourcing is something that many manufacturing companies use, in order to purchase those components that they are not self-produced. These components can be small and have a low price or it can be complex products that are more expensive. It is irrational to put the same effort and time on every component. Those components that are purchased in a high volume and have a high purchase price should have a well done background work with suppliers in order to reach an optimal purchase- and sale price through negotiation. Negotiation is not an obvious choice on components that are purchased to a low price and small quantities. If the goal is to minimize the cost for purchased material, volume value can be the factor that is affecting the categorization. If that is the case the ABC analysis should be use so the A-components need much work, B-components medium work and C-components minimum work. The effects of using ABC analysis when purchasing, the time that a purchaser lays on each component can be rightly divided by the categorization. [Mattsson, 2003]

Variations in the demand are something that cannot be avoided so a safety inventory is used to cover the demand when unpredictable variations happen. Policy defined service levels are the base for dimensions of the safety inventory. Capital- and inventory costs exist when a company has a safety inventory so it is important to calculate the right dimension of it. Components that are crucial, that a lack of that component cause significant implications get a higher proportion of the total capital in the inventory. Those components that not are crucial get a less proportion of the capital because the consequences of a lacking component in this category is not crucial. The ABC analysis can be used so this division is fairly made. [Mattsson, 2003]

It is almost impossible to have a correct balance in the inventory accounting system and it lead to difficulties to avoid shortages and create effective flow of material. It exist two ways to come to grips with this problem, the first is to conduct inventories more often in order to discover errors early and have the opportunity to correct it in an early stage. This method is non-value added work but a resource is needed in order to execute this. The other way to solve the problem is to increase the safety inventory which lead to a less intense inventory. Inventory at a regular basis is the most effective way in order to see the correct balance, this seen from a logistics perspective. Incorrect inventory quantity occurs most often in the in- and outgoing deliveries, because of this, inventory movement scale can be the factor that is used in order to categorize the components. If a company use safety inventory in order to minimize the inventory work, the article value can be the factor for the categorization in ABC. There are some other ways to use ABC analysis, below the goal of the analysis is described and which criteria the categorization that should be used:

- Decrease the capital of the current inventory through minimizing the cost of setup within the production. Volume value should be the criteria in this categorization.
- Dimension safety times due to the non-certain delivery time keeping. The value of the components and average order quantity are the criteria.
- Decrease products in work. The criterion here is the lead times.
- Reach an auto control of error from a progress by using control limits. ABC analysis is in that case using components value.
- Where to place components so the picking order will be effective. Withdrawal rate is the criteria for the ABC analysis.

[Mattsson, 2003]
3.3.1.2. Criteria for selection of procurement strategy

When an article should be purchased it exists two different strategies, purchase to inventory or to order. If a company want to deliver to order one condition is that the delivery time should at least correspond to the replenishment lead time. The possibility to deliver with right delivery time can exist but the strategy to purchase to order may not be the right chose anyway. It is the economic that the chose depends on, it can be better to choose the strategy to purchase to inventory instead. [Mattsson, 2008]

Many companies use simple criteria when they should chose purchasing strategy. One of the most common ways to do it is to start looking at the number of customer order in a year or the number of removal of inventory in a year. It is logical that these criteria is used but only takes into account to the costs involved in selected chose, mainly ordering cost and warehousing cost. The quantity of orders, number of orders per year, storage location costs and picking costs are also affects the choice of strategy. [Mattsson, 2008]

It exist downsides by purchasing to inventory, tied up capital and the company get depended at unsecure forecasts. Articles in inventory risk getting unsalable if they have an expired date or if the technology is developed so the articles in inventory gets outdated, these risks disappear if the strategy choice land on order. [Mattsson, 2008]

Methods with continuous demand

This method helps to decide if the purchasing should be done to inventory or order if the demand is continuous. If the sum of warehousing costs and ordering costs, when the articles is purchased with optimal order size, is less than the sum of ordering costs, when an article should be purchased to orders and with quantities corresponding to each customer order in a period, it is the inventory strategy that fits best. This method is called SPP-model and describe that a purchase to inventory should be the strategy if:

\[ n \times S > \sqrt{2 \times S \times d \times p \times r}, \text{ie if } n > \frac{2 \times d \times p \times r}{S} \]

\( r = \text{inventory factor per year [%]} \)
\( p = \text{price per piece} \)
\( S = \text{ordering cost per purchase time} \)
\( d = \text{demand in a year} \)
\( n = \text{number of orders in a year} \)

[Mattsson, 2008]

This model is based on an assumption, price per unit is independent if the article kept in stock or not and that the ordering cost is the same whether it is purchased for inventory or customer orders. This model has one lack, all costs that are affected by inventory is not in this model. In addition to this it exist another model that take all the cost affected by inventory into account, see the model below:

\[ n \times S > \sqrt{2 \times S \times d \times p \times r + n \times k_1 + k_2} \]

\( k_1 = \text{picking cost per pick from inventory} \)
\( k_2 = \text{fixed cost for stocking per year} \)
The decision criterion for purchasing to inventory is:

\[
n > \frac{\sqrt{2 \ast d \ast p \ast r}}{S} + \frac{k_2}{S} = \frac{\sqrt{2 \ast S \ast d \ast p \ast r} + k_2}{S - k_1}
\]

[Mattsson, 2008]

This model is based on economic order size according to Wilson’s formula and assumes that a lack never occurs but lacks do occur. That leads to lower warehousing costs and give therefore the opportunity to rise to a more optimal order size. There is a model that takes the lacking into account when economic order quantity (EOQ) should be calculated. This model ignores the lacking costs and focus instead of warehousing cost, since that cost change when the inventory change in amount of articles. The result of this model show the total cost (the sum of ordering costs and warehousing costs).

\[
TC(total\ cost) = \frac{S \ast d}{Q} + \frac{p \ast r \ast Q}{2} - p \ast r \ast b + \frac{p \ast r \ast b^2}{2 \ast Q} + n \ast k_1 + k_2
\]

\[b = \text{average shortage quantity per inventory cycle}\]
\[Q = \text{quantity}\]

[Mattsson, 2008]

**Methods with discrete demand**

Spare parts have a low and unpredictable demand which sometimes lead to that a company decide to not have an inventory or only have a one piece of every article, as a safety inventory but there are a few models that take this into account. Two of these models are based on discrete demand, average quantity for every order and on expected number of orders. The two different models have also different terms in order to choose strategy, purchase to inventory or order. With this, it means that the two models should use different decisions models. [Mattsson, 2008]

**The first model**

The importance of replenishment lead time is also taken into account in the first model. This model has their focus on situations that always deliver from inventory if the right quantity is available and that any defects is being backordered for delivery when the next replenishment order is delivered in. In order to use this model several assumptions have to match. The first is that the time from order to delivery is zero, if the article is in inventory otherwise the time is the same as replenishment lead time. The second assumption is that the replenishment lead time is less than the time between two following orders. In both the first and second model it is assumed that the inventory management occurs with a system where the ordering point is negative one since the customer accepts a delivery time that is the same as the replenishment lead time and an order would not have been bought in advance. A safety stock is not useful here. The last assumption is also regarding both the first and second models and it says that in these two models it is assumed that all orders concern the average value of the historic order quantities and that the time between two orders would be the same. [Mattsson, 2008]
If purchasing should be to inventory the formula below should apply.

\[
n > \left[ \frac{3 \cdot p \cdot r \cdot d \cdot lt}{4 \cdot S} + \frac{2 \cdot k_1}{S} \right] + \sqrt{\left[ \frac{3 \cdot p \cdot r \cdot d \cdot lt}{4 \cdot S} + \frac{2 \cdot k_1}{s} \right]^2 + \frac{2 \cdot p \cdot r \cdot d}{s} + \frac{4 \cdot k_2}{S}}
\]

\(lt = \text{replacement time for replenishing stock [year]}
\(n = \text{amount of orders per year for the article}
\(k = \text{quantity on average per customer order for the article}
\(b = \text{lacking quantity on average when orders could not be delivered fully}
\(d = \text{demand}
\(p = \text{price per piece}
\(r = \text{inventory factor}
\(S = \text{ordering cost}
\(k_1 = \text{picking cost per pick from inventory}
\(k_2 = \text{fixed cost for stocking per year}

[Mattsson, 2008]

The second model
In this model the focus is on situations that always deliver with a delivery time that corresponding to current replenishment lead time. A positive factor in this model is that a company can provide the same and known delivery time to their customer in advance. As in the first model there are several assumptions that have to match in order to use this model. The first assumption to the second model is that the time from order to delivery is the same as replenishment lead time. The second assumption is the same as in the first model, that the replenishment lead time is less than the time between two following orders. [Mattsson, 2008]
The last assumption is described above, in the first model.

If purchasing should be to inventory the formula below should apply.

\[
\frac{S}{k} > \frac{S + k \cdot \frac{1}{n} \cdot n \cdot p \cdot r}{2 \cdot k} + \frac{n \cdot k_1 + k_2}{2 \cdot k \cdot \frac{n}{2}}
\]

\(n = \text{amount of orders per year for the article}
\(k = \text{quantity on average per customer order for the article}
\(p = \text{price per piece}
\(r = \text{inventory factor}
\(S = \text{ordering cost}
\(k_1 = \text{picking cost per pick from inventory}
\(k_2 = \text{fixed cost for stocking per year}

[Mattsson, 2008]

Order bound material planning’s methods are the right choice if a company has a low degree of processing orders in which the final production order corresponding to a specific customer order or if the company has standard products where the final production order is equivalent to a series in a production program and manufacture and purchase of articles on the underlying structural levels to some extent only made directly in this series. These methods
are not suitable when it is difficult to forecast the demand as in spare parts for example. [Mattsson, 2010c]

**Most common methods in Swedish companies**

In order to decide if an article with acceptable delivery time, when it is purchased to order, instead should be purchased to inventory it is possible to use a decision model or criteria so it consistent assessment can be executed. [Mattsson, 2008]

A survey has been executed on several companies to reach information on which factors companies use in order to decide if an article should be purchased to inventory or to order. The result of the survey showed several different factors and different combinations and those were:

- Manual assessment
- Number of orders per year + manual assessment
- Turnover per year
- Number of orders per year + turnover per year
- Number of orders per year + manual assessment of how critical an article is
- Number of orders per year + value of an article
- Manual assessment of how critical an article is
- Number of orders per year + turnover + manual assessment + lead time

According to the surveys result, the most common way to decide if an article should be stocked is to check the number of orders per year, at second place is the turnover per year. These criteria is simple to use and the information that the method is based on is easy accessible to companies and is used in business systems (ERP- system) available at the market. [Mattsson, 2008]

### 3.3.2. ORDER POINT SYSTEMS

The definition of order point:

("The quantity of an item that is on hand when more units of the item are to be ordered") [QFINANCE, 2012a]

Sequentially the organizations operations can be divided into three activities; purchase, manufacturing and delivery, shown in figure 3. In the ideal organization articles are not purchased before an order has been received. The time that it takes from a purchase to a complete delivery is called the Logistic Lead Time (LLT), therefore the time from that the customers place an order until they receive their delivery is the so called LLT. Depending on where in this process the actual customer order point lays the company will have to handle different solutions. [Lumsden, 2012]

![Figure 3 (Lumsden, 2012)](image)

The customer has the need for articles by some pre-decided specific times point, delivery times. The delivery time up to this point is totally based on internal conditions and the
requirements that are set. This means that the time from order to delivery, customer lead time (CLT), is limited due to a number of parameters, which are hard to affect. This customer order cycle has a tendency to decrease in time and a customer who has been offered a shorter lead time will not accept a longer one. This leads to a constant decrease in lead times. The CLT should be longer than the LLT the reason for this is that the LLT includes all the activities that are linked to one specific orders implementation. [Lumsden, 2012]

During this time the company has the ability to plan for all of the three activities; purchase, manufacturing and delivery. The alternative is to manufacture according to plan, Make-to-order (MTO) alt. Make-to-plan (MTP). [Lumsden, 2012]

The time difference between the LLT and the CLT is defined as the lead-lag. This lag could be expressed as the time from that the LLT starts until the customer order has been registered, the customer order point and it is this lag, or gap, that the company is forced to handle or eliminate by building an inventory. [Lumsden, 2012]

Order point system is a material planning method which is built up on a comparison between the quantity that is available in stock and a reference quantity called order point. When this reference quantity level has been reached, an ordering is made that tells the purchaser, in the aftermarket case, to refill the inventory, which means that a purchasing process starts in order to procure the articles required to reach the replenishment quantity. Figure 4 illustrates this and the vertical lines illustrate the replenishment. [Mattsson and Jonsson, 2003]

The order point quantity concerns the expected consumption during the replenishment lead time and a safety stock quantity that works as a security against unpredictable variations in the demand. [Mattsson and Jonsson, 2003]

Depending on when the comparison between order point and inventory status is being made there are two main types of order point systems. One is a system with continuous comparison and the other is a system with comparison at given intervals. The first type with continuous comparison matches the theoretical order point method. In practice this means that the comparisons are made with each transaction, when the inventory is decreasing. In the other case with comparison at given intervals, the comparison between the actual inventory status and the order point is made for example once a week. If the actual stock level is less than the
order point at the given time that it is being checked, then an order suggestion is made. This means that an order suggestion is created, in the ERP-system, every week and this is what the purchaser then works with. The companies then have to follow this rule:

“Plan a new order if the reported inventory level and the eventually planned incoming deliveries is below the order point. Then set the delivery time to the date of the day plus the articles lead time.” [Mattson and Jonsson, 2003, p. 251]

With this period-inspection-system the planning of new orders as an overall work commitment can be made. This means that a large amount of articles can be ordered at the same time, which leads to a more efficiency administration. If a company uses the other system with transaction-inspection-system the work to plan new orders will happen more by article. The work input will with this get a more point wise character. The period-inspection-system makes it possible to coordinate the orders to the same supplier in a totally different extent and this will decrease both ordering- and transport costs. [Mattson and Jonsson, 2003]

To exemplify the order point system it can be seen like this:

The consumption of an article during the lead time is approximately 20 and the safety stock has been calculated to be 6. At a certain time the inventory level is 22. The question is if the company should make a new purchase or not? [Mattson and Jonsson, 2003]

With the information that is available a company can see that the order point is 20 + 6 = 26. The inventory level is 22, which is less than the order point; therefore a new purchase should be made. [Mattson and Jonsson, 2003]

3.3.2.1. Consumable Replacement System

Traditional order point systems are characterized by the fact that new in-deliveries occur with varying intervals and constant order quantities. In many contexts it is better to do this in the opposite way. To get in-deliveries at constant intervals and let the order quantities vary and to meet the actual consumption that has occurred during the latest delivery interval. One example of this is when many articles are purchased from one supplier. With this method a company can reduce both ordering cost and transport cost by ordering a number of, or all, articles within one delivery. This will lead to more frequent deliveries and reduce the tied up capital and get increased flexibility as a result. It can also be a plus if a company manage to coordinate the transport from different suppliers. [Mattson and Jonsson, 2003]

This order point system belongs to the period-inspection-system. The system is treated as a category of its own and is called consumable-replacement-system and is a way of working with order points and order quantity all together. For this system a balance level and a refill level is specified. It is calculated as the sum of expected consumption during the lead time and the inventory refill interval plus a safety stock. The length of the inventory refill interval is decided so that the average of the order quantity corresponds to an economical order quantity. The refill level is adjusted according to changes in demand. The rule in this case is:

“Plan a new order with an order quantity that corresponds to the difference between the refill level and the actual inventory level. Set the delivery time to the end-time for the next inventory cycle for that specific article.” [Mattson and Jonsson, 2003, p. 252]
Figure 5 shows the connection between the ways that as an order quantity choose the
difference between the refill level and the actual inventory level and that as an order quantity
choose the sum of consumption from the latest ordering. In the figure, $S(1)$ and $Q(1)$ represent
the refill level. Together they also represent the total quantity that has been available since the
last ordering. Since $S(2)$ represents what is still in stock, the sum between $S(1)$ and $Q(1)$ and
the remaining quantity of $S(2)$ represents what has been consumed during the last interval and
this is what needs to be ordered. [Mattson and Jonsson, 2003]

3.3.2.2. Run-out time planning
In an order point system the order point excluding safety stock is dimensioned so that the
quantity that is in stock when this occurs will cover the demand during the replacement time.
The dimensioned order point is then expressed as a quantity. Something that can be done is to
express the order point as time instead of a quantity and this is called run-out time planning.
[Mattson and Jonsson, 2003]

Run-out time means the time that the available inventory is supposed to cover. This time is
calculated by dividing the available inventory with the expected demand per time unit and as
for normal order point systems the expected demand can be decided by for example statistics
or forecasts. [Mattson and Jonsson, 2003]

In order to prevent uncertainty and variations in the demand during the replacement time a
sort of safety time is used in run-out time planning. This safety time times the demand per
time unit represents the safety stock that is being used in normal order point systems. Here the
rule is:

“Plan for a new purchase if the run-out time minus the safety time is less than the
replacement time. Set the delivery time to the date of the day plus the articles lead time.”
[Mattson and Jonsson, 2003, p. 254]

This way of working can be done by either period-inspection or transaction-inspection and
has the same advantages and disadvantages as for traditional order point systems, 3.3.2.1.
[Mattson and Jonsson, 2003]
An example of run-out time planning:

The run-out time planning system is used to plan for a range of articles. For one of these articles the consumption has been estimated to 12 per week. The lead time for this article is 3 weeks and due to some uncertainties a company wants to keep it one week extra in stock. At one point the inventory level of this article is 54, should a new purchase be made? [Mattson and Jonsson, 2003]

Since the inventory level is 54 it can be calculated that the inventory will last for another 54/12 = 4, 5 weeks. This run-out time is longer than the lead time plus the safety time 3+1 = 4. This means that the company can wait with the new purchase. [Mattson and Jonsson, 2003]

3.3.2.3. Kanban – Direct call-off method

A popular term nowadays is Kanban, a method that has been developed in Japan in connection with Toyota. This means that the manufacturing or purchasing for new articles in this case, will not occur until an actual order has been placed. The extent of this is directly depending on the size of inventory that is needed to have depending on a lot of different reasons. This can for example be that the lead times are way too long or that the ordering costs are too high to be able to make a new purchase every time a new order is placed, it is then more convenient to purchase bigger batches at once. [Mattson and Jonsson, 2003]

These Kanban methods are also called direct call-off methods and are characterized by the fact that an order is not planned and registered by an administrative system, instead the purchase ordering comes directly from the consuming unit. This is what is called a pull system. [Mattson and Jonsson, 2003]

There are two types of Kanban methods, the first one is based on a physical or visual initiation of new orders and the other is based on an administrative initiation. The first one belongs to traditional Kanban and the other is called electronic Kanban or Faxban in some contexts. [Mattson and Jonsson, 2003]

These methods are more common in manufacturing organizations and not so much when it comes to the aftermarket. [Mattson and Jonsson, 2003]

3.3.2.4. A comparison of different order point system ((s,Q)-, (s,S) - and (s,Q-\(p\)) - system)

In a traditional order point system with a fixed EOQ, the fact that the average number always is less than the ordering point when an order is made is ignored. Three methods can be used in order to adjust the EOQ to a more correct. If the EOQ is calculated with an increased average covering (the difference between ordering point and inventory on hand at the order time) a more correct order quantity is reached. An ordering point system is an inventory management method that is based on a comparison between inventory on hand added with outlying orders and a reference quantity for determining whether a new replenishment order should be scheduled. The three methods differ with regard of how the replenishment quality is adjusted for the size of inventory on hand at the ordering time. These differences affect both tied up capital and inventory management cost. The comparison is done for ordering point system with daily comparison of balance and ordering point, this is the most common in the industry business. [Mattsson, 2010a]

(s,Q)-system is the classical ordering point system and is using a fixed EOQ, Q. In this system, the fact that the inventory on hand is below the ordering point when a purchasing is done is ignored. (s,S)-system however, takes that factor into account where the S stands for
replenishment level. The order quantity in a \((s,S)\) - system is the difference between the replenishment level and the inventory balance at the ordering time. The sum of the ordering point and EOQ result in the replenishment level. Calculate average value of covers and then add the quantity to the EOQ is another way to take the balance into account when it is below the ordering point. This approach means that the order quantity is fixed at the same way as in the \((s,Q)\) - system. If the situation has a low demand (many periods without any demand) the average value need to be calculated for those periods where the demand is greater than zero because it is only in these periods that the ordering point can be undercut. That system is called \((s,Q-p)\) - system. A more theoretically correct value on average cover per period can be obtained by using the following formula. [Mattsson, 2010a]

\[
\mu_{cover} = \frac{\sigma^2 + \mu^2}{2\mu} - \frac{1}{2}
\]

\(\mu = \text{average demand per period}\)

\(\sigma = \text{standard deviation of demand per period}\)

[Mattsson, 2010a]

**3.3.2.5. Two bin system**

This method use order point system in order to plan the flow of material. It is based on a comparison between the quantity in inventory and a reference of the quantity (order point). When the order point is reached an order is put and the order quantity is fixed. The characteristic of this form, Two bin system, of order point system is that the order point represents the physical quantity in a tray and not the quantity that is registered in an administrative material management system. [Mattson, 2010d]

Figure 6 illustrates the Two bin system:

![Two bin system](Mattsson. 2010d)

The Two bin system consists of two bins, bin A and B. The bin A is smaller than B. When a Two bin system is started to be used, the quantity in bin A is an estimated or calculated order point quantity, bin A is dimensioned to handle that amount of an article. Bin A is also filled to the right quantity every time the inventory is replenished. [Mattson, 2010d]

The quantity in the larger bin, B, is the quantity that can be consumed before the order point is reached. As long as material exists in bin B, the picking occurs from there. When the bin B is empty the picking occurs from bin A instead. When the picking starts from bin A, when the order point is reached, a signal is send that replenishment needs to be done. This signal can be of different kinds. One example for solution is that it exist a red and green card or another visual signal system on the storage location. When picking from bin A begins the tray is
turned from green to red. At regular intervals a purchaser, material planner or a supplier go through the inventory and note which articles that need to be replenished. Another way to solve the purchasing is that the employee that starts to pick from bin A scan a barcode on the picked article. The scanned information transfers to the company’s business system, in order to show that it is time to replenish the inventory. The order quantity represents an economic or estimated fixed order quantity. When an in-delivery occur the quantity in bin A is restored, the rest of the quantity is placed in bin B. A prerequisite for a Two bin system to work with that design is that the order quantity is larger than the consumption during the replenishment time. If this criteria not is fulfilled the Two bin system can be used with a modified version. [Mattson, 2010d]

When an employee needs to start pick from bin A an order is put in the same way as described previous. The difference is that a card is placed in bin A that an order has been done and that all in-deliveries are placed in bin A. If there already is a note there that an order has been put but is not delivered yet the picking occur from bin A. When the in-delivery comes the note is removed and a quantity correspond to order quantity minus the quantity that is required in order to reset the order point quantity transfer to bin B. Picking continue from this bin. [Mattson, 2010d]

A Two bin system is in first way used to control low valued articles and articles where the consumption is low and predictable. Indirect material is also an application area. Short lead times for replenishment are an important environment factor in order to this method to work with satisfaction. This method is advantageous to use in environments where it is expensive to calculate the amount of quantity that has been picked and to provide accurate balances since the Two bin system do not demand any accounting on the inventory. It is the physical quantity at the storage location that determines when replenishment should occur. [Mattson, 2010d]

3.3.3. METHODS TO DECIDE ORDER QUANTITY

The definition of economic order quantity:

“The most economic inventory replenishment order size, which minimizes the sum of inventory ordering costs and holding costs” [QFINANCE, 2012b]

Order quantity is which amount an article should be purchased in.

3.3.3.1. Economic order quantity according to Wilson’s formula

The base problem of inventory control is to decide an order quantity. There are several different methods that can be used to calculate optimal order quantity, they can be divided into two groups. The first groups of methods are those who are built on the assumption that the demand is continuous, the most well-known and used in this group is the Wilson’s formula. The second group contains methods that are based on assumption that the demand exist of discrete individual needs. One of the methods that are used from the second group is the lowest unit cost method. It is not only the demand that differs in these two groups, they differs within the extent of how they can be based on estimated demand derived from historical information. It is about the forecast; it can be a request of detailed and accrual information about the demand in the future. Those methods that are in the first group, with continuous demand methods, can be based on forecasts on the demand for the future. For those methods in the second group, the discrete ones, in order to give an added value they required information about known future needs in the form of reservations from sales, orders or manufacturing. In those cases where the detailed information is not available for the methods in group two is it necessary to trust methods that are based on forecasts and can assume to have continuous demand distribution. [Mattson, 2007]
Variation in demand is when the demand is low frequent and discrete within planning environments so this assumption, to use Wilson’s formula, is not reasonable. Spare parts distribution is one example that has a vary demand. Lowest unit cost is a method that is based on discrete needs and is not useful because it is built on the information access about the discrete needs that will occur in the future, for example in the form of reservations or decreased needs from the structured levels by using material requirements planning. It is interested to see how the existing methods can be modified so new will be developed so they will fit the reality better. Simulation can be a useful tool when a method will be tested if the method has the ability to give reasonable optimal order quantities. [Mattson, 2007]

Products should exist in inventory so the delivery time gets as minimal as possible. A safety stock should also exist in order to ensure an acceptable level of service. Optimal order quantities and safety stock are factors that are depending on each other, this leads to an easier way to calculate them separately and that is how it is done in the practice. Because of this and since simultaneous calculations is very complicated and require an iterative procedure, included with methods that are based on that order quantity and safety stock can be calculated separately. When the calculations should be evaluated with simulation the consequences is seen separately. [Mattson, 2007]

It do not exist an exact method that is able to solve the problem, the customer orders in a year and consumption occasions are not continuous. Wilson’s formula that calculates EOQ is based on continuous and constant demand [Mattson, 2007].

\[
EOQ, \text{ according to Wilson's formula } = \sqrt{\frac{2 \times O \times E}{P \times r}}
\]

\(O = \text{ordering cost}\)
\(E = \text{demand per year}\)
\(P = \text{price per piece}\)
\(r = \text{inventory factor per year [%]}\)

[Mattson, 2007]

When the optimal order quantity should be calculated it can be positive to take into account to the mutual dependence between order quantity and safety stock. It exist a model that do this, it is based on that the lack cost can be estimated. The method is complicated to calculate and requires an iterative procedure but there is another method that is simplified. That method is constructed in two steps, first a calculation of the EOQ separately by using Wilson’s formula. In step two the order quantity that are the highest after the calculation is chosen and so is the order quantity that is equivalent with standard deviation during lead time. Through this complementation the optimal order quantity does not differ much from the calculated order quantity with Wilson’s formula for articles that have large fluctuations in demand. This method gets close enough to the optimal order quantity that a more complicated method is not necessary. [Mattson, 2007]

In order to use this method that consists of an amount of formulas it should be possible to estimate, through history, mean time between customer order and medium order quantities and it can be assumed that the calculations is done after the customer demand of orders, received by these intervals and for quantities corresponding to these order quantities. [Mattson, 2007]
\[ EOQ = -d \times lt + k \times \sqrt{\frac{(2 \times d \times lt)^2 + 2 \times d \times S}{4 \times k \times k} + \frac{2 \times d \times S}{k \times k \times p \times r} - \frac{d - lt}{k}} \]

\( d = \text{demand per year} \)

\( lt = \text{replacement time for replenishing stock} \)

\( k = \text{quantity on average per customer order for the article} \)

\( p = \text{price per piece} \)

\( r = \text{inventory factor} \)

[Mattson, 2007]

### 3.3.3.2. Lot-sizing techniques

The quantity of an order should cover the demand that exist or is expected. One way to decide the order quantity is therefore correspond to individual requirements which mean that a new order should be created for every need and that this order quantity corresponds to the demand. [Mattsson and Jonsson, 2003]

If the order quantity is decided from a manual evaluation the decision is based on experience within the size of the demand, prize of the articles and the cost of putting an order, no calculation is done. The methods that are based on calculations are economical optimized methods. Both these methods try to minimize the sum of ordering- and holding cost that lies as a foundation for the dimension of the order quantity. [Mattsson and Jonsson, 2003]

An order quantity can be expressed as a quantity or as a time period where the order quantity covers the demand. If the method expresses the order quantity as a quantity the result can be used direct in the material planning but if it is expressed as a time period the order quantity needs to be calculated associated with the material planning. When an initiated needs method is used the sum of net requirements under the several periods that corresponds to the time. If the consumption initial method is used the order quantity calculation is based on a share of the annual consumption under a whole year. [Mattsson and Jonsson, 2003]

#### 3.3.3.2.1. Estimated period requirements

The needs coverage time means that the order quantity is chosen so it will cover a whole number of planning periods, weeks or days. This method can be used both manual and with economical calculations, the order quantity is specified as a time expressed in an amount of periods in the ERP- system register of articles and register of warehouse. The order quantity can be calculated in two ways, the first is to sum the forecast needs, reservations and material requirements that have been broken down from overlying structure level over the amount of periods that has been chosen. The order quantity changes since the demand changes. [Mattsson and Jonsson, 2003]

\[ Q = Q_Y \times \frac{PR}{W} \]

\( Q = \text{Order quantity} \)

\( Q_Y = \text{Estimated annual demand} \)

\( PR = \text{Period requirements} \)

\( W = \text{Number of weeks to consumption} \)

[Mattsson and Jonsson, 2003]
### 3.3.3.2.2. Economic period requirements

The only difference between the estimated period requirements and economic period requirements is how the period requirement is calculated. Economic period requirements can be calculated as a balance between the ordering costs and inventory costs. The simplest way to reach there is to start calculate the EOQ and then calculate the economic period requirement in periods. If the period requirements are calculated at this way the average order quantity is the same amount as the EOQ. [Mattsson and Jonsson, 2003]

\[
\text{Economic period requirements} = \frac{EOQ}{D}
\]

EOQ = is calculated as above, 3.3.3.1.

\[D = \text{average demand per period}\]

[Mattsson and Jonsson, 2003]

When the Economic period requirement has been calculated, the formula in 3.3.3.2.1 is used to calculate the order quantity (PR is replaced by the economic period requirements).

[Mattsson and Jonsson, 2003]

### 3.3.3.2.3. Silver–Meals method

Silver–Meals method which is also called least period cost method (LPC) is one of the most used methods within dynamic lot sizing methods. It is based on information around the product that handles quality, time and discrete demand. The theory behind this method is based on the fact that the inventory cost is equal to the ordering costs that occur when the order quantity is optimal. When a new order should be placed calculations is executed gradually, if a period of quantity should cover the order. This method is optimal if the demand is relatively known. Silver–Meals method calculates the order quantity so a full period is able to meet the demand, similar as the period requirement is calculated. [Mattsson and Jonsson, 2003]

Silver–Meals method is based on the average sum of inventory costs and ordering costs per period and from that it is possible to get the information on how many periods of demand one order should cover. The order quantity corresponds to an amount of periods demand that result in the lowest average incremental cost per period. It is a sequential method since it sequential handles the demand in the future periods. When the order quantity should be calculated the method uses four steps. The different steps are exemplified below. [Mattsson and Jonsson, 2003]

Step 1: Calculate how many months demand one order with in-delivery in January should cover.

Average sum of incremental cost per month is:

If one month is included: \(4000 \text{ SEK}\)
If two months are included: \(\frac{(4000+1000)}{2} = 2500 \text{ SEK/month}\)
If three months are included: \(\frac{(4000+1000*2+1000)}{3} = 2333 \text{ SEK/month}\)
If four months are included: \(\frac{(4000+2000*3+1000*2+1000)}{4} = 3250 \text{ SEK/month}\)

The lowest average incremental cost per month is obtained if the order quantity corresponds to three months demand. A new order should be planned to be placed in April.
Step 2: Calculate how many months demand one order with in-delivery in April should cover.

Average sum of incremental cost per month is:

- **If one month is included:** 4000 SEK
- **If two months are included:** \((4000 + 2400) / 2 = 3200\) SEK/month
- **If three months are included:** \((4000 + 4400*2 + 2400) / 3\) SEK/month

The lowest average incremental cost per month is obtained if the order quantity corresponds to two months demand. A new order should be planned to be placed in June.

Step 3: Calculate how many months demand one order with in-delivery in June should cover.

Average sum of incremental cost per month is:

- **If one month is included:** 4000 SEK
- **If two months are included:** \((4000 + 3000) / 2 = 3500\) SEK/month
- **If three months are included:** \((4000 + 2400*2 + 3000) / 3 = 3933\) SEK/month

The lowest average incremental cost per month is obtained if the order quantity corresponds to two months demand. A new order should be planned to be placed in August.

Step 4: These calculations continues at the same way to the planning horizon.

If the Silver-Meals method is used the inventory cost will increase compared to period requirement method but since the amount of order is decreased the total incremental costs are decreased. [Mattsson and Jonsson, 2003]

3.3.3.2.4. **Least total cost method**

Even Least total cost (LTC) is based on the optimization between ordering costs and inventory costs. The sum is optimal when these two costs is equal, which means that the goal is to minimize the total incremental costs, not the total incremental costs per period which was the goal in the Silver-Meals method. In LTC an order should be placed in the first period where the inventory cost exceeds the ordering cost. When a new order has been planned the calculation process starts from the beginning. In the Silver-Meal method it were four steps to go through and it is the same with the LTC method. The different steps are exemplified below. [Mattsson and Jonsson, 2003]

Step 1: Calculate how many months demand one order with in-delivery in January should cover.

The comparison between inventory cost and ordering cost is:

- **If one month is included:** \(0 < 4000\) SEK
- **If two months are included:** \(1000 = 1000 < 4000\) SEK
- **If three months are included:** \((1000*2 + 1000) = 3000 < 4000\) SEK
- **If four months are included:** \((2000*3 + 1000*2 + 1000) = 9000 > 4000\) SEK

The inventory costs are lower than ordering costs if order quantity is equal to two or three months demand but the cost gets higher if it corresponds to four months demand. The order quantity should correspond to three months demand and therefore a new order should be placed in April.

Step 2: Calculate how many months demand one order with in-delivery in April should cover.
The comparison between inventory cost and ordering cost is:

If one month is included: 0 < 4000 SEK
If two months are included: 2400 = 2400 < 4000 SEK
If three months are included: (4400*2 + 2400) = 11200 > 4000 SEK

A new order should be placed in June since the order quantity should cover two months demand.

Step 3: Calculate how many months demand one order with in-delivery in June should cover. The comparison between inventory cost and ordering cost is explained by the example below:

If one month is included: 0 < 4000 SEK
If two months are included: 3000 = 3000 < 4000 SEK
If three months are included: (2400*2 + 3000) = 7800 > 4000 SEK

Since the inventory costs is lower than the ordering cost if the order include two months demand but not if it include three months, a new order should be placed after two months, in August.

Step 4: Continue to calculate in the same way until the planning horizon is reached.

If the LTC method is used the lowest incremental costs will be reached compared to other lot-sizing techniques. [Mattsson and Jonsson, 2003]

3.3.4. DIMENSIONING SAFETY STOCK

The definition of economic safety stock:

“Inventory held as buffer against mismatch between forecasted and actual consumption or demand, between expected and actual delivery time, and unforeseen emergencies. Also called reserve inventory.” [Business Dictionary, 2013]

In order to satisfy customer with a high service level a safety stock is important. A safety stock would not be necessary if everything always went as planned and no conditions were to be changed but in real life that is very unlikely so it is necessary to handle a safety factor. Customers demand is not always continuous and the delivery from a supplier can be delayed. A safety stock is used when something go wrong, by using the safety stock the company has the possibility to deliver to their customers without any disturbance. Delayed in-delivery (if promised lead time is not kept), deficiencies in in-delivery (if the inventory cannot complete an order the safety stock needs to be used) and increase of the demand (the inventory do not have enough amount to cover the increased demand so the safety stock is used to a new delivery comes). The size of the safety stock depends on how big the insecurity is and which delivery services the company wants to give to their customers. [Aronsson, Ekdahl and Oskarsson, 2004]

Figure 7 illustrates how a safety stock can change and be divided.
To decide the level on the safety stock, which is a difficult task, it is helpful if a good knowledge about how lead times and demand vary is available. Knowledge about which level the service should be on is also necessary in this task. The goal is to reach as high service as possible at the same time the cost is minimal. [Aronsson, Ekdahl and Oskarsson, 2004]

A survey shows how Swedish companies do when they decide their safety stock. Approximately 50% of Sweden’s companies base their safety stock calculations on intuitive and experience assessment. Almost 25% use a markup on the consumption and 5% do not use safety stock. Only 25% of the respondents base their decision about the safety stock on a specified service level which is the right way to make the calculations according to the theory. It exist other methods that base their calculations on a cost comparison for impaired delivery service and inventory costs but estimate of shortage cost is often more difficult than estimate the demand and lead time vary. [Aronsson, Ekdahl and Oskarsson, 2004]

3.3.4.1. Dimension to service level
In the following section methods that have an uncertainty in the service level are described.

Uncertainty in demand
As long as articles exist in inventory variations in the demand are not a problem. The problem surface when the inventory starts to run out, if the lead time is long it will take a long time to replenish the stock which leads to a difficulty to handle an increased demand. The size of the safety stock depends, in this case, on three factors, LT (expected lead time), $\sigma_D$ (the demands standard deviation under the lead time) and desired service level, $k$ (the possibility to deliver directly from inventory). The variations in the demand and lead time are assumed to be normal distributed. [Aronsson, Ekdahl and Oskarsson, 2004]

The safety stock against uncertainty in consumption, $SS_D$ is calculated as:

$$SS_D = k \cdot \sigma_D \cdot \sqrt{LT}$$

[Aronsson, Ekdahl and Oskarsson, 2004]
Uncertainty in lead time
In the same way that the demand can vary, the lead time can also vary. If the lead time becomes longer than expected deficiencies will occur, even if the demand is the same as the forecast. Even in this case the calculation is based on three factors, in this case those factors are: D (expected demand under one time unit), $\sigma_{LT}$ (standard deviation for the lead time) and desired service level, k. [Aronsson, Ekdahl and Oskarsson, 2004]

The safety stock against uncertainty in lead time, $SS_{LT}$ is calculated as:

$$SS_{LT} = k * \sigma_{LT} * D$$

[Aronsson, Ekdahl and Oskarsson, 2004]

Simultaneous uncertainty in demand and lead time
In many cases companies have uncertainties with both the demand and lead time. The probability of having problems with both at the same time is minimal and the company does not need to cover two problems at the same time with their safety stock. The safety stock that is needed is therefore less than the sum of the individual safety stock that has been described previous. If an assumption is done that deviations in demand and lead time is completely independently of each other the safety stock, $SS_{TOT}$ is calculated as:

$$SS_{TOT} = k \sqrt{SS^2 + SS_{LT}^2} = k \sqrt{LT \sigma_D^2 + D^2 \sigma_{LT}^2}$$

[Aronsson, Ekdahl and Oskarsson, 2004]

If the uncertainties, demand and lead time not are completely independent the safety stock need to be larger. In those case where the demand and lead time not are normally distributed other methods need to be chosen in order to decide the safety stock. If several measurements exist on the demand and lead time the calculated standard deviation is more certain. By using information that is collected under a long period of time but at the same time be careful with eventual changes the calculations of the safety stock will be optimal. The calculated safety stock should not be seen as a certain truth, it is more like a guideline of how large the safety stock should be. It is possible that a factor that is not included in the formulas is affecting the size of the safety stock so it will be necessary to change the amount of the safety stock manually. A follow-up on the service level should be executed in order to keep the safety stock at the right amount and be able to change it if it will be necessary. [Aronsson, Ekdahl and Oskarsson, 2004]

3.3.4.2. Safety stock based on cost optimization
To use safety stock as a way of avoiding deficiencies means that a company can reduce the costs that the deficiencies will contribute to but the company has to be aware of the fact that this will increase the inventory costs. Because of this it is possible to dimension the safety stock by balancing these shortage costs and inventory costs. The most optimal solution would be to find a way that minimizes both of these costs. The sum of these costs will reach its minimum when the expected cost to have a surplus in inventory is the same as the expected cost to have deficiency in stock. [Mattsson and Jonsson, 2003]

Out of this relation the company can use the following formula to calculate the probability that a deficiency in stock will occur during an inventory cycle, $\Phi(k)$ and with the condition that a deficiency in stock will lead to a decrease in demand:
\[
\phi(k) = \frac{SC}{SC + WC \cdot \frac{Q}{D}}
\]

\(k = \text{Safety factor}\)
\(Q = \text{Order size}\)
\(WC = \text{Warehouse cost per unit or time unit}\)
\(SC = \text{Shortage cost per unit}\)
\(D = \text{Demand per time unit}\)

[Mattsson and Jonsson, 2003]

If deficiency leads to backorders and deliveries at a later time, which means that the demand will not be decrease, this formula is needed:

\[
\phi(k) = 1 \frac{WC \cdot Q}{D \cdot SC}
\]

These connections generally apply for all distributions. It can be assumed that the demand is normally distributed than the company can use a normal distribution table to obtain the same safety factor. Thereafter the company can calculate the safety stock as following:

\[
SS = k \cdot \sigma
\]

\(\sigma = \text{Standard deviation in demand during the lead time}\)

[Mattsson and Jonsson, 2003]

**Example:**
The demand for an item is approximately 200 per year. The order quantity at replenishment is 80 and the price is 50 SEK per item. The standard deviation is 11 and the warehouse cost is 25 % per year. The shortage cost is 20 SEK per item. The deficiency often leads to lost sales, this implies that

\[
\frac{20}{20 + 0,25 \cdot 50 \cdot 80} = 0,8
\]

With the help from table 1, that shows examples of service levels and corresponding safety factors the result is that \(k=0, 84\) and this result in a safety stock at

\[
SS = 0,84 \cdot 11 = 9 \text{ pcs}
\]

[Mattsson and Jonsson, 2003]
3.3.4.3. Dimensioning Methods

When the safety stock is calculated there are a few factors that need to be taken into account. If the difficulties of choosing suitable values for dimensioning variables is ignored every method that is based on calculations is equivalent within tied up capital that is necessary in order to reach a certain service level for an article. Different articles should have different service level. This depends on imperfections in the calculations model that are used in the different methods and the relationship between dimension variables and service level. [Mattsson, 2011]

How suitable a method is in regard of tied up capital that is necessary need to be valued relative to the goal of delivery ability. Different article cost different to have in stock and the contribution to the total delivery ability vary. The most important factor is that it should be different service level in different articles. A categorization is helpful in order to divide them into suitable groups of delivery ability. [Mattsson, 2011]

**Number of days of demand**

The simplest and the most used way of dimensioning the safety stock are to set the safety stock equal to a number of days average demand. By doing this the company will get a higher safety stock for articles with high demand than for the ones that have a lower demand and with this also get a higher demand service. Since the total service demand will be affected more by articles with high demand than the ones with low, it will lead to something good for the service demand. This is because it leads to the fact that every articles service level is weighted with the demand per year. This will also make the articles with high demand to be less expensive than the articles with low demand and this leads to the fact that the safety stocks capital will be less affected by high service levels for articles with high demand. [Mattsson, 2011]

Since articles with high demand often has a lower price than articles with low demand the result in service levels for articles with high volumes are not going to be weighted as much as when demand service are used. There is also a connection between the size on standard deviation and the size on the volume value that results in the fact that increased volume value service is followed out by an increased safety stock. This, leads to a not so beneficial relation between obtained service level and capital. Therefore the company cannot expect that a

<table>
<thead>
<tr>
<th>Service level [%]</th>
<th>Safety factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>50,00</td>
<td>0,00</td>
</tr>
<tr>
<td>75,00</td>
<td>0,67</td>
</tr>
<tr>
<td>80,00</td>
<td>0,84</td>
</tr>
<tr>
<td>85,00</td>
<td>1,04</td>
</tr>
<tr>
<td>90,00</td>
<td>1,28</td>
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<td>95,00</td>
<td>1,65</td>
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<td>98,00</td>
<td>2,05</td>
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<tr>
<td>99,00</td>
<td>2,33</td>
</tr>
<tr>
<td>99,50</td>
<td>2,57</td>
</tr>
<tr>
<td>99,99</td>
<td>4,00</td>
</tr>
</tbody>
</table>

Table 1 (Mattsson and Jonsson, 2003)
number of day’s average demand is an appropriate method for volume value service as a way of measuring the delivery capability. [Mattsson, 2011]

A large demand often corresponds with too many orders and many orders means less demand variations and with that less standard deviations for the demand during the lead time. [Mattsson, 2011]

This seems conductive at a safety stock which is demanding a certain order service. Since the different articles order service is weighted by the number of customer orders, the relation between the total order service and the total capital will be reinforced. [Mattsson, 2011]

**Percent of the demand during lead time**

This method is about dimension the safety stock as a percentage of the demand during the lead time, it is also called a proportionality approach. The safety stock calculation is based on the demand during a number of days since the safety stock size can be expressed as the percentage multiply by the lead time in terms of days multiply by the average demand per day. The difference between this method and the number of days of demand method is that this one adapts the amount of days to the lead time length. The percent method use different levels of service on different articles and is beneficial in regard of the tied-up capital that is necessary for order service and demand service. The ability that this method have, adapt the amount of days to lead time lengths, leads to less articles with a little amount in safety stock when the lead times is long or large safety stock when the lead times is short which can happen when amount method is used. Because of this it is expected that the percentage method will reach a more optimal relationship between the ability to deliver and tied up capital then the amount method. [Mattsson, 2011]
4. EMPIRICS

In this chapter a description of how the thesis has been executed will be presented. It will include a current state description and the benchmarking of four companies.

4.1. CURRENT STATE (MAPPING OF ABB)

ABB develops and construct their own products, some of the components are produced by ABB but some are outsourced. ABB OC SE buys their articles both directly from ABB but also from the suppliers who produce the outsourced articles.

4.1.1. ABB AND ABB OPERATION CENTER

ABB is an industrial company and a global leader in power and automation technologies. The headquarters is located in Zurich, Switzerland and operates in approximately 100 countries with 145 000 employees. [ABB, 2013]

In its current form, ABB was created in 1988 but the company´s history extends beyond that. In 1889 Ludvig Fredhom, Göran Wenström and Jonas Wenström created the company “Elektriska Aktiebolaget” and in 1890 when they merged with “Wenströms& Granströms Elektriska Kraftbolag” and they finally created ASEA (Allmänna Svenska Elektriska Aktiebolaget). ASEA came to play a key role in the development of Swedish industry and in 1988 ASEA merged with Brown Boveri, a Swiss company and became ABB, a world leader in power technologies with a large investment in R&D. This has led to a long track record of innovations. [ABB, 2013]

Today, ABB stands as the largest supplier of industrial motors and drivers, the largest provider of generators to the wind industry and the largest supplier of power grids worldwide. [ABB, 2013]

ABB Sweden

The Sweden offices are located in Västerås and Ludvika together with the main part of the Swedish operation. ABB Sweden has about 8950 employees in 30 different locations of which 4200 in Västerås and 2700 in Ludvika. [ABB, 2013]

ABB Sweden Process Automation (PA)

Process Automation is one of the divisions within ABB Sweden. This division has the responsibility for:

- Development
- Production
- Marketing
- Sales
- Sales support
- Service for automation products within control and monitoring, products and systems for power measurement.

The division is also responsible for solutions when it comes to automation and effectiveness within industries and organizations such as:

- Metal-, Mineral-, Paper-, Chemistry- and Pharmaceutical industry
- Marine organization, crane systems for container handling and industry- and jib cranes. [ABB, 2013]
**ABB Operation Center**

The responsibility of Operation Center is to provide aftermarket products and services all over the world. They offer spare parts, reparations, upgrades and exchange units for a large part of the products that ABB has. With the overall knowledge and experience they provide solutions with availability and speed as their catchwords. Together with other ABB units and customers they develop the future aftermarket concept for industries all over the world. [ABB, 2013]

### 4.1.2. *System 800xA Life Cycle Policy*

ABB OC SE has categorized their products in four groups and these groups depend on which life-phase a product is in. The four different groups are; active, classic, limited and obsolete. The customer needs will be handled differently depending on which of these four phases their product is in and the meaning of a product differs within the groups.

#### 4.1.2.1. Life Cycle Policy Statement

The Life Cycle Policy Statement in ABB describes how their different articles should be handled through their lifecycle.

“ABB’s control systems are designed for continuous evolution. It is ABB’s goal to protect our customers’ intellectual investment (i.e. application software) beyond the life cycles of the underlying platform products (i.e. hardware and software).

ABB will not "Remove from Active Sale" any product or "family" of products until an equivalent replacement to those products is available. Once a product has been removed from active sale, ABB will continue to support the product for at least 10 years, although exceptions to this may occur if components or technologies needed are no longer available to ABB.

Within this support period ABB will announce a “Last Buy” opportunity at least 12 months prior to the end of manufacturing (except in cases where there is a direct form, fit and function replacement). It is ABB’s intention to provide support for as long as there is significant customer needs after the "Manufacturing End" through field service, repair and by making replacement spares (new or refurbished modules) available.” [Internal document, ABB, 2012, p. 8]

#### 4.1.2.2. Active Phase

When a product has been released for sale the product will be in the active phase. In the active phase new products exist which have a normal maintenance. How long a product is in the active phase depends on the market condition, technology advances and hardware- and software components availability to ABB. ABB wants their products to support their customer in that order that an upgrade of a system has a minimal impact on their processes and that is why one factor is to develop and market products that do not affect their customer’s process that much.

#### 4.1.2.3. Classic Phase

It is the product manager that decides when a product should be removed from the active phase and be placed in the classic phase instead. The responsibility for a product's maintenance lies on the Product Management and Development. The maintenance in this phase is limited to changes of a product, which depends on the supplier’s obsolescence of components. It can also depend on a problem that is hidden and have a serious impact on the product operation (business critical problems). If a product switch phase from active to classic, a notice to all sales channels will be sent at least 12 month before the transition. If that
product is replaced with another product that has the same form, fit and function upgrade the announcement can be bypassed. It is the sales channels that have the responsibility to transfer that information to the end customer within a reasonable time so the customer has the possibility to buy the product that is going to the classic phase.

Products can be a last buy, product management send out a notice six months before the transition but sometimes it has to be shorter because of the notifications from the supplier. When a product is last buy a customer has 12 months to buy it and then the volume manufacturing ends. When a product has reached this status the support and manufacturing has ended.

4.1.2.4. Limited Phase
When the product has entered the volume-manufacturing end the product goes into the limited phase. The responsibility of the product lies no longer at product management, it has transfer to the service department at ABB OC SE instead and so is the product support. It is the product management together with service that decides what internal information that is needed or if other items are needed for long-term support and decide the transfer arrangements. The service support in this phase lies on the field service, workshop repair and the sale of refurbished spare parts. These services and support are being done as long as the knowledge and spare parts exist. How long this support phase is depends on the improved return of a valuable hardware. ABB has a guarantee on the classic phase combined with the limited, the guarantee support the article 10 years after it goes into the classic phase. There are exceptions, if a product no longer is available at ABB, there will be an upgrade of the product that will be offered to the customer.

4.1.2.5. Obsolete Phase
When ABB cannot guarantee technical support, when it is about knowledge or spare parts the products enter the obsolete phase. It is the product management that takes that decision after a discussion with the selling channels. Despite this, the service organization can be able to support the product if they have spare parts available in the inventory. The sales channels will get an announcement at least six months before a product enters the obsolete phase.

4.1.2.6. Exchange
ABB offers a service called exchange, which means that a customer can receive a spare part, refurbished or new (depending on the availability), the customer orders a spare part and then has 30 days to send in the broken part to ABB. ABB has then two chooses, the first is to repaired it and if that is not possible or to expensive they have the chose to scrap it. With this service the lead times are at the minimum for a spare part, it is also cost-efficient. This service is available in all phases of a product. [ABB, 2013]

How the amount of articles changes through the lifecycle is visualized in figure 8.
4.1.3. ABB'S PURCHASING STRATEGY TODAY

ABB OC SE, formerly Logistic Center, offer spare parts to their customers. When they purchase new parts to the warehouse they sometimes start with an amount of two, but this is depending on earlier consumption, and then the amount is regulated in order to be more conforming to the demand. The reason for the low amount of purchasing in the beginning for newly released articles depends on the child diseases, problems with the product in the first stage of the product life. If a product has a lot of child diseases many customers chose to use the exchange system (4.1.1.6.) instead of purchase a new product.

ABB OC SE has 13 big suppliers, they buy from about 90 suppliers yearly and in a four year period they buy from approximately 380 suppliers. All the suppliers have different lead times, prices and contacts. The longest lead time is 18 months.

Their products are today categorized according to the life cycle model (4.1.1.) and product families (central unit, communication modules, I/O modules and power supply), when it comes to automation products. A few years ago they had a category of critical articles but today that category has been deleted, due to the lack of ERP-support, it is today adjusted with the order point.

ABB OC SE only handles the aftermarket so from their perspective, aftermarket is a large part in their operation. But they can also stand for new products if it is needed immediately. They think that aftermarket is a positive and necessary factor to the whole ABB group.

When a purchaser shall decide the amount of an order they base the decision on history. Because of revisions they are using FIFO (first in, first out) when an order is packed and shipped, that is because they do not want old revisions in inventory for a long time.

They are also use the strategy EKA, which is presented below:

4.1.3.1. Purchasing Strategy

ABB OC SE has their focus on cost-conscious growth with help from three approaches, efficient work methods, cost focus and attractive purchasing function (EKA).

Efficient work methods
In order to ensure profitability, growth and business, ABB do not have another choice then to make the operations more efficient. They try to find time to develop the business in order for
it to lead to an optimized process and in order for it to meet customers and client’s new requests and demands. Encourage creativity which generate an improvement of routines, so they do not get stuck in the obsolete methods is another way that ABB OC SE try to reach efficient work methods. They are also trying to improve their result of the business development work and the usage of the structure that they have been building up.

ABB OC SE have used SWOT analyze in order to get an understanding of what their strengths, weaknesses, opportunities and threats were. From the SWOT analyze they realized that they have weaknesses that need to be improved for bounding inventory and inventory planning. They have also realized that their work is not standardized so that a purchaser can decide how and when to purchase.

The purchaser at ABB OC SE has a system support that supporting their business model. They have the knowledge that is needed in order to cover others (purchasers) work areas. ABB OC SE are getting more and more articles to handle and they need to know when they should scrap/liquidate them. A process for purchasing does exist that ABB PA and ABB OC SE should use but in the end it is the purchaser that makes the decisions.

**Cost Focus**

To be able to increase their competitiveness, ABB OC SE tries to do it through availability and growth. In order to increase the value for the customer they strive for the right inventory, high service and a good relation with their suppliers. They strive to increase ABB’s profitability by focus on decreasing the total cost. They need to develop the inventory planning in order to get it more efficient. The purchase process also needs to be more efficient. Some problems that they have are the low volume, the obsolete level and the fact that suppliers’ stops supply them with articles.

**Attractive Purchasing Function**

When the world changes ABB OC SE needs to develop their work so they in the future will feel comfortable with the changes. In order to succeed it is necessary to have a good climate to work in and have the ability to develop on a personal level. All of the employee’s ability, knowledge, skills, experience, commitment and creativity are vital to the company’s success. The gathered skills in the group make it possible for ABB OC SE to be profitable and a growing organization. Good leadership conditions are created for the employees within ABB OC SE and it makes them attractive employers.

The purchaser at ABB OC SE uses target stock, a kind of order point, in order to know when they should make a purchase to the supplier. When the amount of an article in inventory reaches the target stock the purchaser will put an order to the suppliers. Target stock is based on, lead-times, previous consumption and price. To some suppliers that have their own production, MOQ (minimum order quantity) and batch size are two additional parameters. The articles in the inventory that are slow movers (80%) have a target stock of 50% of one year consumption, if the article is not MOQ. If the article is a MOQ that is larger than half a year’s consumption the target stock and batch size will be decided according to the MOQ. It is the purchaser that sets the target stock based on these parameters.

When the purchaser should decide how many of an article that should be purchased they look at parameters such as, replenishment lead time, consumption and price. In some cases they have a fixed batch size, it depends on which supplier they order from. When the article is moving frequently or if it should be purchased in a larger volume they use Wilson’s formula.
Last Time Buy (LTB) is one problem that the purchasers at ABB Log C encounter. Another problem is that they do not work after a specific process. They only have one process they follow to the fullest and that is a process that handles scrapping.

If an article does not exist in the selection and customer need it, it is possible to do a redesign but then it is the customer that has to pay.

Interface- and OD meetings are their way to find the problems and then try to solve them. An old problem was the scrapping but through their interface- and OD meetings the scrapping processes were improved.

Before they knew which country the order was sent to but not which town, today it is mandatory to register the end user. They also know which software a country has available. Some of the customers purchase to their own inventory so when they have a breakdown they have the spare part available immediately. The customers use SOFA, Software factory, and my control systems.

Nowadays the focus has switch from spare parts to service. It is 5-10% of a system´s life time that spare parts stands for. Today the customers are better at handling preventive maintenance and the lead-times from production is shorter, this leads to a decrease in rapid delivery. [Appendix 9.3.]

4.2. BENCHMARKING
A benchmarking on four companies has been done in order to compare their different strategies.

4.2.1. ALFA LAVAL
Alfa Laval was founded in 1883 by Gustaf de Laval and Oscar Lamm and is today a large international group. [Alfa Lava, 2013]

The focus of Alfa Laval lies on energy optimization, environmental protection and food production, through technical leadership in heat transfer, separation and fluid handling. They have over 300 patents and are providing the society with solutions that are vital today and for the future. [Alfa Lava, 2013]

Alfa Laval are continuously trying to protect their leadership on the global market and are known for focusing on innovation and new ways of thinking. They are investing about 2, 5% of their sales in R & D which results in between 35 and 40 new products every year. [Alfa Lava, 2013]

Alfa Laval is a worldwide organization that helps customers in nearly 100 countries with process optimization. They have 28 production units; 15 in Europe, 8 in Asia, 4 in USA and 1 in Latin America. Today they have 16 000 employees, mostly located in Sweden, Denmark, India, China, USA and France. [Alfa Lava, 2013]

4.2.1.1. Alfa Laval Interview
Alfa Laval has totally seven places for spare parts and Tumba is one of them. Different sites handle spare parts for different product groups, one of them are separators. Total in all sites, there are around 200 000 articles in active status. The most frequent articles, that belongs to stocked items (SI) is approximately 20 000. The rest of the active items are order bound. In Tumba, Sweden, there are about 58 000 active articles and 9 500 of these are SI. The aftermarket at Alfa Laval, parts and service stands for approximate 33% of the company’s
whole operation but in Tumba they only handle the aftermarket so it is very important for them. They handle the aftermarket for separators which is important because a separator has a lifetime of 40 years.

Alfa Laval sends many of their orders to other departments within the Alfa Laval group. A customer that is big is Tetra Pak, they get a forecast from them so they can estimate how much that will be needed. From other customers it is up to Alfa Laval to make a forecast but they think it is difficult since the aftermarket is so uncertain.

In Tumba they work with Business Development (BD) continuously in project form. Today they have a project that is about a vary demand, when they think they have reached a solution they can test it in one place before they start to implement it globally.

When it comes to problems availability and inventory value are the two biggest that exist in Alfa Laval, when it comes to inventory management and the aftermarket. To improve and solve these problems they have their monthly process where they look at their month order lines to see what has been sold and how much. Sometimes they start a project in order to figure out how to improve and solve a problem. When Alfa Laval in Tumba need to solve the problem fast they usually try to make the lead times shorter with the suppliers.

They are using lean and Six Sigma when they do improvement work. In order to reach improvements Alfa Laval in Tumba has meetings daily and works toward Alfa Laval Production system. Some of the problems are solved immediately while other problems can turn into projects. Once a week they have improvement meetings.

The aftermarket is important to Alfa Laval since their customers buy from them because they have a high quality.

Alfa Laval has a large amount of suppliers, which they see as a disadvantage with externalizing but they have two advantages, which are, Alfa Laval cannot produce every article by them and they get better service from their suppliers.

The material management department at Alfa Laval in Tumba would like to improve their communication with those who work in the warehouse. Today the office sends the monthly overview to those who work in inventory so they will be updated on the changes.

Some articles lies in the inventory a long time but Alfa Laval are working to improve the scraping process. Today they scrap 1-2 times/ year and it is how long an article has not moved that is the deciding factor.

Sometimes the problem with articles that stops being produced occurs. Spare parts are bought from other Alfa Laval offices but also from other suppliers. As long as the machines that are producing the article are working, the article can be produced (when they are buying from Alfa Laval). They have an ongoing project, to start their own spare parts production. It has existed for four years but it is not until now they have started to use it more widely. If it is not possible to produce the article it can often be replaced by another part but it is necessary to see if the new article fits. Sometimes Alfa Laval is informed that the article no longer will be produced and then Alfa Laval can look for other suppliers or develop a replacement part. In order to satisfy the customer needs, Alfa Laval has a guarantee of 10 years.
Information about the customers

The history of orders is saved so they can use that information to make estimates for a forecast. They try to reach a Delivery On Time (DOT) at 97% over the whole Alfa Laval group, their customers do not think Alfa Laval reaches that goal and that is a global problem.

Their customers are divided by country and different people handle different countries. Today they use FIFO (first in first out) on their orders but are investigating now if they should have customers that are more important and that should be prioritized.

Methods do decide whether to have stocked- or order bound items

Alfa Laval categorizes their articles in four different groups, SI, NI, RI and BI. It is 20 000 article in the group SI. NI stands for Non-stocked Item, they do not exist in inventory but Alfa Laval has a supplier for those articles with price and delivery time. RI is Requested Items, they do not exist in stock and they do not have a supplier, so the articles are available in the system but are uncertain. The fourth group is BI, Business Items, these articles exist because they are important for the customers but does not sell as much as SI.

SI, NI and RI have been the categorization for a long time. BI is relatively new, Alfa Laval thought something was missing and developed BI approximately four years ago.

To know which articles that should be in SI, Alfa Laval checks the number of order lines, not amount. 95% of all the order lines are supposed to be stocked.

In order to know which products and how many of them that should be in inventory Alfa Laval does a follow-up once a month. They have a safety inventory and a service inventory. They have 96% availability at the SI. SI is divided in five groups, A, B, C, D and E. The articles in group A are the ones that are most frequent, 99, 4% (delivery dependability), group B has 97%. The different percent of delivery dependability are evaluated once a year, this depends on the economic situation in the world. Group A and B together stand for 80% of all order lines in SI. It is 90% in group C where the articles are medium frequent, which group stand for 15% of all order lines. The last 5% of the order lines belong to both group D and E, group D has 70% and group E 50%, they risk ending up in an order bound group. This method is used to know how many is purchased, safety and order quantity (that is calculated with Wilson´s formula). All of these parameters are evaluated once a month so Alfa Laval can improve and manage their purchasing. This strategy was developed by all seven offices that handle the aftermarket because they wanted to work in the same way, which they today do.

Alfa Laval has been working with this strategy for approximately five years and they can see improvements, they work globally now and can support each other when it is necessary. All offices get an overview and the work can be divided at the different distribution areas.

The inventory turnover lies on 2-2, 5 times a year.

Order point systems

The business system at Alfa Laval calculates the order point as following:

They want a delivery when their ATP (Available to Promise) is lower than the safety stock.

\[
ATP = On\ hand\ balance + Outstanding\ purchase\ orders - Outstanding\ customer\ and\ manufacturing\ orders - forecast
\]

This formula calculates what ATP is at the lead time, if the lead time is 10 days it compares
the ATP 10 days ahead with the safety stock. The purchase order is in that case created 10
days before the ATP at the lead time is below the safety stock.

**Methods to decide order quantity**
The order quantity is evaluated with help of the Wilson´s formula. As a maximum they buy
for a half-year consumption (unless the supplier has a minimum quantity that they have to buy, in those cases they buy it anyway.)

**Dimension safety stock**
The most frequent articles (that stands for 80% of the order lines) get their safety stock calculated by the following formula:

\[
Safety\ stock = Safety\ factor \times 1.25 \times MAD \times \sqrt{lead - time}
\]

*The safety factor is decided due to the service level*  
*\(MAD= Variation\ in\ consumption\)*

For the middle- and low frequent articles the safety stock is decided with the help of the Poisson table (not normally distributed).

**Delivery dependability**
The delivery dependability is calculated when the goods is picked, packed and ready to be shipped out from the warehouse (dispatch date). The dispatch date is compared with the first confirmed date to the customer. Early deliveries are ok but only if the customer wants it that way.

They have also started to measure the delivery dependability according to when the customer has received the goods.

**4.2.2. Atlas Copco**
Atlas Copco is a world-leading supplier of solutions for industrial productivity and was founded in 1873. Innovation is something that they have been focusing on since the company started and the core of the organization is the same up to this day, although the products today are a lot more effective. [Atlas Copco, 2013]

Their products and services concern everything from gas- and air compressors to plant- and mine equipment and also industrial tools and assembly systems. [Atlas Copco, 2013]

Some of their products are; compressors, expanders, air treatment systems, power tools and services for aftermarket and rental. [Atlas Copco, 2013]

Atlas Copco manufactures products in over 20 countries and by 2011 they had 37 500 employees. Their products are being sold or rented under various brands in over 170 countries and in half of these Atlas Copco has wholly or partly owned customer centers. [Atlas Copco, 2013]

The vision of Atlas Copco is to be and remain “First in mind – First in choice”. This means that they should be the first ones in mind and at choice, when it comes to customers and other key stakeholders. [Atlas Copco, 2013]
4.2.2.1. Atlas Copco Interview

Atlas Copco has three distribution center (DC) and one of them is located in Örebro. They handle Mining and Rock excavation technique and Mining and Rock service (MRS), they are also responsible for the development within logistic. Atlas Copco produces parts to the drilling machine that they have the knowledge and technique for (the core business) the other articles are bought from suppliers.

The DC in Örebro delivers spare parts to Underground Rock Excavation (URE), Surface Drilling Equipment (SDE) and Geotechnical Drilling Equipment (GDE). MRS has the responsibility to control the inventory and decide what articles should be in the inventory at DC.

The DC is built in a way such as it has a reception for incoming goods, an inventory and outgoing stations for both light goods and heavy goods.

Atlas Copco sees a need for spare parts and they are investing in the aftermarket. They want to be able to deliver good service, which has increased over the years.

When a customer makes an order they can chose between three different types, these types are break down, urgent (when a product soon will break) or replenishment. The break down orders is prioritized.

Atlas Copco group make customer surveys two times a year, sometimes they can have a specific theme. DC does a survey once a year and this is done on the ten countries that are the biggest customers. Faster response to the customer (except the customer in Australia because of the time difference) is one improvement that has been done due to the result of the customer surveys. Another improvement the customer surveys had leaded to is that every department in the MRS use the same tools which makes the customers satisfaction increase.

If a backorder should occur, Atlas Copco contacts the supplier for the article and they try to solve the problem together. If a customer has order to many articles they have the opportunity to cancel the order. DC makes an evaluation on their suppliers so they can satisfy their customers.

Picking errors is one problem at Atlas Copco in Örebro and in worst case it leads to availability errors. These errors are noted when the warehouse does not have all of the articles in stock or when the inventory is done. Atlas Copco in Örebro is using 5S to improve the working routines and working processes. Storage space is another problem and this is one of the reasons they use extern storage place for SAC3 items. A problem that DC has had was that their glass articles was delivered broken to the customers, they have solved this problem together with their suppliers with better packing material.

Purchaser communicates with strategic purchasing and the goods receiving. The goods departure communicates with the customer service who handles the shipping.

**Methods do decide whether to have stocked- or order bound items**

Atlas Copco in Örebro have approximately 200 000 articles for sale but only 34 500 that exist in inventory, they are called SAC1 and SAC3 (can contain articles that are critical or order bound, they have a few more in inventory). They are also categorized after the weight and product family. Every article is being inventoried once a year.

Atlas Copco have articles that is categorized as dangerous goods but they do not want to handle it themselves so they use an extern entrepreneur that are packing those articles.
It is the SAC code that decides if an article should be a stocked item or not. In SAC1 the stocked item is categorized and in SAC3 the articles are mostly order bound but they do not have to be. The SAC code is updated monthly according to the yearly frequency (how many times in a year that the article is requested).

If an article is being sold four times in one year the article must exist in inventory, if it does not sell four times in one year the article becomes order bound. So an article in inventory should have a turnover of 90 days. Some articles are always order bounded even if they sell frequently and that can depend on the fact that some articles have an expiration date and can therefore not be hold in inventory for a longer period of time.

**Order point systems**
The forecasting support system, SCC, calculate the order point based on volume value and picking frequency for a given service level. The calculations are based on the demands history and the forecast of sales.

The purchaser use a matrix called SCC to know how much to purchase and when they should purchase, it is based on a 12 month history. In the matrix the purchaser insert parameters like, how many are consumed, lead times and the value, the result changes every month. Even though the matrix calculates for the purchaser, the purchaser can regulate it manually. This method has been used by Atlas Copco in Örebro for approximately 7-8 years.

**Methods to decide order quantity**
When the order quantity should be decided Atlas Copco in Örebro uses their forecasting support system, SCC. The system calculate the order quantity based on the volume value and picking frequency for a given service level. There are the demand history and forecast of sales that are the foundation for the order quantity.

The articles that exist in SAC3 can lie in inventory a long time because Atlas Copco is forced to buy a bigger amount of articles than they want. If an article lies in inventory two years without moving, the article gets scrapped.

**Dimension safety stock**
In order to dimension the safety stock it is the SCC system that make the decisions, just like when the order quantity and order points are decided. Even here the decision is based on the demand history and forecast of sales. All available components exits in a safety inventory, both stocked- and order bound items.

**Delivery dependability**
The delivery quality is defined as “rightly delivered to customer”. That means that it should be the right article, right amount and that the goods are not damaged (the article should be cultivable for the customer). The goal is that 99, 77% of the order lines should be correct.

Despite the picking problems Atlas Copco in Örebro has a goal to deliver 99, 77% of the orders right and this is followed up every month.

When an article stops being manufactured there is often a replacement. Strategic purchasing is working with critical articles and collaborates with the suppliers in order to come up with the best solutions for the end customer and does not have only one supplier that can deliver an article but several for better security.
Atlas Copco in Örebro has a goal for the shipping performance at 98, 5% and 99, 77% delivers with the right order lines, that are quality. The transportation is mostly done by airplane.

Atlas Copco in Örebro is trying to improve the in- and outgoing process for goods. The last years they have worked a lot on improving their inventory availability. Their goal is to have an inventory availability at 97% but are striving for 97, 6%. This has led to a bigger safety stock. To get a high availability, Atlas Copco in Örebro strives to have a close communication with the suppliers.

4.2.3. Bombardier Transportation
Bombardier has long history of innovation. In over 60 years they have been taking on some of the hardest challenges in their industry. The problems are being solved through creativity, entrepreneurial energy and hard work. They are creating new techniques, improving the old ones, changed the way of leading and in that way become a leading company within their industry. [Bombardier, 2013]

The company was founded in 1937 by Joseph-Armand Bombardier who developed the first band vehicles for mail delivery, emergency care and school transports. [Bombardier, 2013]

Today Bombardier has 64 production sites in 26 countries and 19 maintenance centers all over the world. They are the leading company in the rail industry. They offer everything that has to do with the rail industry and signal systems and have today over 100 000 railcars and locomotives installed worldwide. [Bombardier, 2013]

Today Bombardier has 36 000 employees and can deliver products like:

- Rail vehicles
- Drive- and control systems
- Services
- Bogies
- Transport systems
- Signal systems

[ Bombardier, 2013]

4.2.3.1. Bombardier Interview
Bombardier transportation in Västerås produces parts for trains, which are a big investment. How Bombardier’s aftermarket is divided can be seen in figure 9. The inventory is divided into three different smaller inventories, EWR (Eldivision, Warranty and Repair), ESS and EWS (Eldivision, Warranty and Spares). In EWR there are many articles, ESS is their main inventory but they do not have many articles there. In EWS they have placed loose articles and the selection of articles is wide. They also have an extern inventory which is order bound and that inventory lies under ESS. ESS is built on consumption and needs. The EWS inventory is available for ESS to buy from.
Bombardier’s aftermarket department handles EWR and EWS, in EWR there is 90 pcs and in EWS 850 pcs. It is the sales department that handles the ESS inventory but it is approximately 15-20 pcs. Most of their articles do not exist in inventory they are order bound.

The articles that the aftermarket department handles are not categorized more than are showed in figure 9 but they are thinking about categorize them according to the ABC method.

Within the aftermarket department at Bombardier in Västerås they see the aftermarket as a factor that is not only important but also necessary for Bombardier as an organization. Another important factor why Bombardier’s aftermarket is important is that their products have a lifetime on 30 years. The aftermarket is about 10 % of the whole Bombardier group and their turnover lies on 15 million SEK.

In the ESS inventory they look back at one year’s history in order to make their forecasts. This is not always the most optimal way to handle this since their lead times can be somewhere between 40 weeks to one year. They are now working to implement the 80-20 rule, they will try it because the method that they used before is not working as they want. The goal they want to reach with the new method is to make the lead times shorter.

Bombardier is currently working with BD, continuous improvements. All employees is available to tribute to the development, Bombardier urges everyone to come up with six improvements in a year, they can be both small and big improvements and the employees have improvements meeting every week.

One problem Bombardier has is their guarantee inventory, they have the articles but has sometimes problem to know what articles should be in a kit when a customer should do maintenance. Other problems they have is long lead times, customers want to be able to repair locally. In order to solve the last problem, Bombardier is thinking of starting an exchange system.

They are not able to measure the inventory turnover rate but their main inventory has a turnover of 7-10 times per year.

Sometimes articles stop being produced by a supplier and in those cases Bombardier mostly find some replacement product and if they do not they try to make a redesign.
Bombardier keeps customer number, contact information, payments terms, delivery terms and VAT number. They save this information because they want to ensure a fast and safe handling when they have contact with the customer. Quickness is a competitive factor within the spare parts. In order to see how satisfied the customers are Bombardier makes surveys but not in every department. Bombardier’s customers are divided in three different segment, Key Accounts (KA), intern and extern. The intern group is divided into smaller groups, Mainland, Boggie, Service and Joint Ventures. The only differences in the groups’ strategies are how to set a price. The customer that is in the KA group has one specified seller but the other customer does not.

Bombardier only sees positive factors by using externalizing and those are, shorter lead times, the supplier has the right knowledge and it is time- and money saving.

They have not noticed a decrease on their market of spare parts, in fact, they have seen a factor that suggests increasing both of spare parts and trains. They are aware of the fact that Euromaint makes repairs and are big in the business.

**Methods do decide whether to have stocked- or order bound items**

It is the guarantee project leader that decides which articles that should be in inventory or order bound in EWS inventory and it depends on the project. The administrative logistician has the responsibility to decide if articles in the EWR inventory should be in stock or order bound. The decisions are based on one year’s history. It is the most frequent articles (max 100 pcs) that exist in inventory.

**Order point systems**

The administrative logistician decides the order point for EWS inventory. For the EWR inventory an order point is not used, they put orders quarterly and the amount is then so it will be enough for a year. Then the administrative logistician, every quarter, reconciles the amount of articles so there is no excess inventory. If the articles run out before the next replenishment a new purchase is being done manually.

**Methods to decide order quantity**

When a new article is purchased, the amount is so many that should be in inventory. The changes of the amount depends on the lead times and costs. It is the administrative logistician that decide over the EWR inventory and order every quarter, one year amount of an article is purchased at once and at the same time the responsible person determines how many to purchase so it will not be excess inventory. If the articles run out before next replenishment the inventory is filled by an extra order.

For EWS the order quantity has been decided with the first order then the amount depending on how many articles that get sold.

**Dimension safety stock**

Bombardier in Västerås does not have any safety stock because they do not have the space for it. They do use a Two bin system in order to secure the delivery after the customers demand. This system is used in EWR

**Delivery dependability**

The delivery dependability is not calculated on an inventory level. It is only on a finished repaired product the delivery dependability is calculated. Bombardier in Västerås have an end date (set of the sale- or warranty department) in agreement of workshop planner that register
in a program, SOMT (a planning program that is used for the repair), then the start- and end date are reported. They have a follow-up with an OTD-curve.

4.2.4. **Volvo Construction Equipment**

In 1832 Volvo Construction Equipment (VCE) was founded in a machine shop in Eskilstuna Sweden and it is the oldest company in the world that is still active within the construction machinery. [Volvo Group, 2013]

Volvo CE is today a global company with its main part located in Eskilstuna. During the years the company has dealt with mergers and acquisitions. Up till today the company has had more than forty different names. [Volvo Group, 2013]

In comparison with the industrial development in the mid-1800s and the favorable climate in Sweden during this time, three energetic technical talents made room for their ideas and innovations. These three engineers named Johan Theofron Munktell, Jean and Carl Gerhard Bolinder became, due to their technical genius and enthusiasm, the founders of what today is known as Volvo CE which combines state-of-the-art technology with over 180 years technical and industrial traditions. [Volvo Group, 2013]

4.2.4.1. **Interview Volvo**

Volvo Group – Logistics Services DC Eskilstuna (Volvo LS DC) supplies VCE’s customers with spare parts. Volvo CE produces construction machinery. They are striving for a product portfolio so that a customer can perform work (e.g., build a highway) with only Volvo machines. The most important factor for Volvo LS DC is to satisfy the customer so they will have as high uptime as possible. They want to give good service to Volvo and their other customers.

Volvo LS DC´s work tasks are decided by Volvo CE, they should procure, store and distribute. They should also be best and easy to deal with within the business. They decide what articles should exist in Volvos inventory all around the world. In order to know which articles that should lie in inventory they look at factors such as, which machines are available in which countries which parts that are critical, is there an important customer in this country, actual sales. Along with these factors a forecast is done.

The largest spare parts such as engines, power trains, cabins, etc., they get from Volvos own production but smaller components are bought in from other suppliers. Volvo LS DC offers remanufacturing parts, this is done in Flen. Volvo LS DC in Eskilstuna is the central warehouse, they deliver to support inventory, dealers and regional inventories. Volvo have recently gone through a reorganization, before it was called Volvo Parts, now it is called Volvo Group – Logistics Services DC Eskilstuna. Volvo LS DC is located at four places in Europe - Eskilstuna, Gent, Columbus and Lyon. In Gent´s inventory there are some CE-articles but it is the office in Eskilstuna that has the responsibility for them. They have 800 customers in 108 countries.

When a customer place an order they can chose to order for breakdown, day order or stock order. It is breakdown order that has the highest priority, those orders is send to the customer the same day as Volvo Parts receive the order and has 99,9% delivery performance. If a customer place a day order Volvo will send the article the day after they received the order and the delivery performance is 99, 8% for day orders, stock orders are minimum 98%. Volvo LS DC in Eskilstuna has sometimes short of time when they receive orders. They can get an order 45-60 minutes before the truck comes to pick up the order. They send the goods mostly by plane from Arlanda, Stockholm but also from Örebro.
One problem that Volvo LS DC in Eskilstuna has is that some of their articles do not exist in inventory, which makes it difficult to reach the goal of 94% service level. Other problems are that some articles that should be in inventory do not exist in inventory; in order to solve this problem the backorder team is investigating why this happens. Errors of the stock quantity, to high stock value, an article can lie 5-10 years without moving and the design of their articles are a few more problems at Volvo LS DC.

In order to not have articles in inventory that almost never moves they have a regular process of scrapping. They want to be involved in the product development phase in order to tribute to a design that is more appropriate to stock.

In the Operational Development (OD) all employees should be involved, they have meetings every second week and once a month they have a lager meeting. At Volvo it is decided that the boss cannot be the leader of the OD meetings, it has to be a team member. It is not only the work that should be developed, every employee should be to and in order to reach that goal Volvo have three guidelines. An employee should do their work, develop the work and develop themselves.

Methods do decide whether to have stocked- or order bound items
Volvo LS DC has 600 000 articles available for their customer, when it comes to the Volvo CE articles. It is 137 500 articles that have a frequent movement and in Eskilstuna’s inventory there exists 75 000 articles. Those articles that are least frequent are stocked at other warehouses in Eskilstuna.

Volvo LS DC are categorizing their articles by the lifetime which are divided into four different classes, initial, prime, deadline and phase out. They do also work with a categorization that is depending on the frequency of an article.

Volvo has a stockholding policy which from different logistic perspectives and an articles function puts up parameters and indicates if the article should be order bound or not. The material handler in charge can also manually make decisions (within given authority).

Order point systems
The order point is based on the safety stock, EOQ and expected consumption during the purchasing lead time + transportation lead time + time for reception of goods

Methods to decide order quantity
This is based on the individual articles volume value and the reception of the goods total capacity through iterative simulations.

Dimension safety stock
At Volvo the safety stock is based on the lead time from the supplier, consumption and variations in consumption. Generally they strive to have as high service level as possible for low-cost articles and critical articles and therefore have a bigger safety stock for those articles.
5. ANALYSIS AND DISCUSSION

Here the four research questions will be presented and analyzed. The theory and empirics is compared in order to reach different solution concepts.

5.1. METHODS TO DECIDE WHETHER TO HAVE STOCKED- OR ORDER BOUND ITEMS

In the theory, 3.3.1, three methods are presented. These are the ABC analysis 3.3.1.1, where the articles are divided into groups and the volume value is what decides what group the article should be in. These groups can then be analyzed again and divided into subgroups. If a product according to the ABC analysis ends up in category C, it is then up to the company to decide whether this particular article group should be stocked- or order bound items. Another method is the one that helps to decide if purchasing should be done to inventory or order if the demand is continuous, 3.3.1.2. There are two formulas that calculate this; one is based on inventory factor, price per piece, ordering cost, demand and number of orders. The other one also includes picking cost and fixed cost. The last one is a method that handles discrete demand. There are two formulas: the first focuses on situations that always deliver from inventory if the right quantity is available. This is based on replacement time, replenishment, amount of orders, quantity on average per customer order, lacking quantity, demand, price per piece, inventory factor, ordering cost, picking cost and fixed cost. The second formula focuses on situations that always deliver with a delivery time that corresponds to current replenishment lead time. This formula is based on amount of orders, price per piece, inventory factor, ordering cost, picking cost and fixed cost.

The theory also describes combinations of several methods that are used in Swedish companies. The most common ones are to check the number of orders per year and to check the turnover per year.

Alfa Laval

From a visit at Alfa Laval in Tumba, the knowledge that they categorize their articles into four groups (4.2.1.) was received. These are; SI, NI, RI and BI. SI, which stands for all the SI, is then divided into five subgroups; A, B, C, D and E. The different groups have different goals of delivery dependability and group A and B together stands for 80% of all the order lines, C stands for 15% and group D and E stands for 5%. According to forecasts these different groups and subgroups are evaluated once a month. The different percent of delivery dependability are evaluated once a year, this depends on the economic situation in the world. These standards are implemented globally. All Alfa Laval aftermarket units are working in the same way and the turnover at Alfa Laval, Tumba, lies on 2- 2.5 times a year.

Atlas Copco

Atlas Copco has divided their articles into two different groups called SAC1 and SAC3, 4.2.4. It is the SAC code that decides if an article should be a stocked item or not. In SAC1 the stocked item is categorized and in SAC3 the articles are mostly order bound but they do not have to be. The SAC code is updated monthly according to the yearly frequency (how many times in a year that the article is requested).

Some articles are always order bound due to the fact that they have a short expiration date. The other articles status depends on the turnover, if an article has a turnover of 90 days or less the article must be in inventory and if not it is order bound.

Bombardier

The administrative logistician has the responsibility to decide if articles in the EWR inventory should be in stock or order bound. The decisions are based on one year history and only affect the most frequent articles (max 100 pcs).
Volvo
Volvo LS DC are categorizing their articles by the lifetime which are divided into four different classes, 1) initial, 2) prime, 3) deadline and 4) phase out. They do also work with a categorization that is depending on the frequency of an article.

Volvo has a stockholding policy which from different logistic perspectives and an articles function puts up parameters and indicates if the article should be order bound or not. The material handler in charge can also manually make decisions (within given authority).

5.1.1. DISCUSSION
In these discussion parts an analysis and discussion of the different methods will occur in order to find advantages and disadvantages. A comparison between them and the different company’s strategies will also be made.

As mentioned in section 3.3.1.1. the ABC analysis is a well-used method in order to categorize the different articles and to decide if the articles should be order bound or stocked. This is a desirable factor when a company handles many different articles of a large variety and it can be used both in a manufacturing company as well as in a division that only handles aftermarket. One of the main goals with this analysis is to separate the important articles from the less important ones. Normally the articles will be categorized according to the volume value but the possibility to adapt the categorization factor so that it fits the company’s goals, which may not necessarily be to improve the volume value. Instead the goal may be to manage the profitability, here it would be more convenient to use margin as the categorization factor instead of the turnover, 3.3.1.1.

By categorizing the articles the company has the opportunity to set up different goals and strategies for different groups. This is something that has been done by Alfa Laval, 4.2.1., where they have divided the articles according to how important they are for their customers and the frequency. Alfa Laval has named the categories differently than ABC. They have also chosen to use four groups instead of three, they have different strategies for all of these groups. This shows that the company can develop the method in order to get it as suitable as possible from their point of view. Both Alfa Laval and the theory advocate that the use of subgroups is to prefer in order to be more specific. This means that the articles in the main groups are categorized within themselves. For example Alfa Laval has five subgroups to one of their main groups. These subgroups have different goals to live up to.

Something that is worth mentioning is difficulty to keep track of where an article is placed, since the parameters will change over time. It does not matter what categorization factor that is being used, the articles will most likely move both within the subgroups and also the main groups. Worth mentioning is also that the theory points out the evaluation and change of group should not be done that often. This could lead to problems in the fact that the company does not know where the article is placed. Articles may have the tendency to stay in the same group for a longer period of time. When the employees know which group the articles lie in it is easier to keep up with the changes that occur in a group. If these problems occur, it is most likely that the method is not being used at all, which in turn will lead to even more disorganization. Although Alfa Laval do their check-ups monthly they manage to keep track of their articles but if a categorization is not used at all, it will be even more difficult to keep track of the articles and manage the inventory.

Atlas Copco, 4.2.4., has chosen to categorize their products into stocked items, SAC1 or order bound, SAC3. Like Alfa Laval, 4.2.1., they have also divided the articles in SAC1 into subgroups where the categorization factor is weight.
As written in section 4.1 and section 4.2.3, both ABB and Volvo are using a life cycle categorization. The belief in this case is that the life cycle categorization is something that most companies are using but in order to be successful the company need to have more concrete categorization of the articles in order to manage the inventory in the most efficient way. The life cycle is a good support for the company, for example ABB is using this to calculate the guarantee times for their customers, 4.1 and it is better to have this categorization than to not have any grouping at all, like Bombardier.

Just like the ABC analysis is used in order to create different strategies, the difference in demand requires different actions. If a group of articles have a frequent consumption then the formula of continuous demand is to prefer but if instead some articles have a more undetermined consumption it is better to use the formula for discrete demand, 3.3.1.2. The formula for discrete demand is the one that is mostly used within the aftermarket since the demand there is varied and very uncertain. If the articles are divided into categories according to for example the ABC analysis, then it will be easier to know which ones to use the different formulas on, either the continuous or the discrete.

Both the theory and three of the companies decide if an article should be order bound or stocked according to the frequency. Bombardier has chosen to put up a maximum quantity of how many items they should have in inventory, 4.2.2. It is good to have a goal of how many articles that should be in inventory. In this way the articles need to be evaluated of how important they are, if they need to be in inventory or not. Even though most of the companies base the decision, if the article should be in inventory or order bound, on the frequency some companies base the decision on the turnover or make a manual assessment.

5.2. ORDER POINT SYSTEMS
In chapter 3.3.2 different methods to decide the order point are described. One of them is the Consumable replacement system. Traditionally the order point systems are characterized by the fact that the in-delivers occur at varied times and the order quantity is constant but this method does it in the opposite way. Here the company has specific in-delivers and the amount of articles varies. With this method it is possible to reduce the ordering- and transportation costs. If the in-delivers can occur more frequently than the order quantity can decrease which leads to a reduced inventory cost.

The length of the inventory refill interval is decided so that the average of the order quantity corresponds to an economical order quantity.

The refill level is adjusted according to changes in demand. Another method to decide the order point is the Run-out time planning. This method is based on the fact that the company calculates the order point so that the amount of articles will cover the replacement time. If the order point or target stock is for example 10, then this number is set so that the company knows that these 10 will cover the demand during the replacement time.

The third method is Kanban or Direct call-off method that works in the way that a purchase is done when the company has received an order from the customer.

There are two types of Kanban methods; the first one is based on a physical or visual initiation of new orders. The other is based on an administrative initiation. The first one belongs to traditional Kanban and the other is called electronic Kanban or Faxban in some contexts.
The theory also handles a comparison of the three most common methods within industries. (s,Q)-system, (s,S)-system and (s,Q,p)-system, they are described in 3.3.2.4.

The last method the theory describes is the Two bin system, this system handles the articles through two bins. The order point is reached when one of the bins is empty, then it is time to place a new order.

**Alfa Laval**
As described in 4.2.1. Alfa Laval calculates the order point with the help of their business system.

They want a delivery when their ATP (Available To Promise) is lower than the safety stock.

\[
ATP = \text{On hand balance} + \text{Outstanding purchase orders} - \text{Outstanding customer and manufacturing orders} - \text{forecast}
\]

This formula calculates what ATP is at the lead time, if the lead time is 10 days it compares the ATP 10 days ahead with the safety stock. The purchase order is in that case created 10 days before the ATP at the lead time is below the safety stock.

**Atlas Copco**
Atlas Copco uses a forecast support system called SCC. This is based on volume value and picking frequency which are based on the demands history and the forecast of sales. This is updated every month. The purchaser has the ability to manually change the order point.

**Bombardier**
Bombardier does not use any order point system. Instead they do everything manually, by checking it quarterly.

**Volvo**
The order point is based on the safety stock, EOQ and expected consumption during the purchasing lead time + transportation lead time + time for reception of goods.

5.2.1. **DISCUSSION**
The consumable replacement system indicates that the purchasing will occur at specific given times and that the order quantity can vary. This means that the company will not have a specific order point, they order when they feel the need to. A positive factor with this is that if the company varies the order quantity and do not have a specific order point then they can avoid excess inventory. If the purchaser sees that they have reached the order point and he or she has to purchase a given quantity of 50 articles but in fact the company only needs 15, then they will get an excess inventory of 35 articles. Another positive advantage with this could be that the company can purchase a higher amount of articles in advance if they, in their forecasts, can see an increased consumption within the near future.

A disadvantage or something that can be difficult in this method is the fact that the company or the purchaser needs to have a really good relationship with their suppliers. The reason for this is because the supplier wants, most of the time, a fixed order quantity so they can plan their own production and purchases. A good relationship with suppliers is possible to have if the company only handles a few. If the company has several suppliers a good relationship such as this requires is difficult to maintain. Through an articles lifetime the quantity will change, in the beginning it will be more frequent than when it reaches an obsolete state. Atlas
Copco is using a similar method or way of thinking, since their system calculates the amount of articles and when a purchase should occur. This happens every month and leads to different order points and order quantities, which this method advocates.

The run-out planning means that the order point is expressed as a time instead of a quantity. Here it is easy to keep track of how many articles that are required in order to cover for example different lead times and it is also an advantage that the company or purchaser easily can use a sort of safety time to prevent accidents in time. If this method is being used within a business system, then the company should be able to decide how often the calculations should be done. A daily calculation on the order point is not suitable if an article lies in inventory a few months, so it is important to be able to change how often the calculation should be done. One company that is using this method, or a part of it, is Volvo. They involve different times and lead times when they calculate their order point.

Kanban is not suitable for the aftermarket since the aftermarket handles a lot of articles and the consumption varies a lot. Kanban is equal to, in a way, having all the articles as order bound, this has already been discussed in the previous part, 5.1.1. In the aftermarket the company needs to have some articles in inventory due to the long lead times. This method is not recommended to use for the aftermarket.

In section 3.3.2.4 a comparison between different order point system is done. When using the \((s,Q)\)-system it is common to end up in the usual problem swamp, which indicates that a new purchase might occur when the order point has already been reached and passed. In other words, the inventory lies on minus. In the \((s,Q,p)\)-system the calculations depend a lot on the demand, different demands requires different ways of calculating them. This method seems a bit too complicated to implement at ABB. They need a more structured and easy start.

Alfa Laval has come up with a method or formula that suits their situation and requirements perfectly. The order point is built up on the fact that they can deliver their articles at the time that they have promised their customers. The fact that they have different goals when it comes to delivery dependability and that they have matched their order point system to this indicates that they are thinking about the whole picture through the entire process.

Bombardier do not use any specific method to calculate the order point, they decide it manually. When they have decided the order point they can decide the amount of the orders so the quantity will cover the demand. For that they use the Two bin system, where the articles are divided into two bins. This leads to the fact that the purchaser gets good knowledge about the articles and knows how the demand changes. This is not suitable for ABB since they handle such a big range of products. However it may be possible to use a manual method on one group of articles but not on all of them, since they are too many. A specific strategy is to prefer, this will give more structure and less unnecessary work. The Two bin system use fixed order quantities and variable delivery dates. It is built on the physical quantity in inventory and not what the data system knows. In order to know when to purchase different technique can be used, either the employees use cards or scanning. If cards are used, someone needs to go through the inventory to see which articles need to be purchased. If this method is used it is possible to miss cards. If that happens the articles are not purchased and there will be a lack in inventory. So if this method is used, it is recommended to scan instead of using cards. If a company do not have afford with that investment and want to use Two bin system they need to use card anyway. If that is the case it is recommended that the size of the cards is developed so the risk of missing an article is minimal. The company should also go through their routines to secure that the checking is being done with regular basis.
It is possible to use a modified version of the Two bin system, 3.3.2.5, this version can be used if the order quantity is not larger than the consumption. The modify version is more complicated and a company want the methods to be simple and easy to use. It is most suitable to small articles that do not take so much space and those articles that have a low but predictable consumption.

5.3. METHODS TO DECIDE ORDER QUANTITY
In the theory section 3.3.3. different methods to decide order quantity are described. The first one is Wilson’s formula. This is a formula that can be used to calculate the order quantity when the demand is continuous, 3.3.3.1. The Wilson’s formula is based on ordering cost, demand, price per piece and inventory factor. Another method is the one that calculates the EOQ. This method describes the relationship between the order quantity and the safety stock. Since the formula is complex there are two different ways to decide the order quantity. One way is to use a formula that is based on the demand, replacement time and quantity on average per customer order, ordering cost, price per piece and inventory factor. The other way is to use Wilson’s formula, then the results from both of the ways are compared and the highest order quantity is chosen.

An order quantity can be expressed as a quantity or as a time period where the order quantity covers the demand. If the method expresses the order quantity as a quantity the result can be used direct in the material planning but if it is expressed as a time period the order quantity needs to be calculated associated with the material planning. When an initiated needs method is used the sum of net requirements under the several periods that corresponds to the time. If the consumption initial method is used the order quantity calculation is based on a share of the annual consumption under a whole year. A few methods describe this.

One method is called the estimated period requirements. This one is based on the needs coverage time. The order quantity is chosen so that it will cover a whole number of planning periods. Another one is called the economic period requirements and can be calculated as a balance between the ordering cost and inventory cost. The silver-meals method is based on information around the product that handles quality, time and discrete demand. Then there is LTC- method. In LTC- method an order should be placed in the first period where the inventory cost exceeds the ordering cost. When a new order has been planned the calculation process starts from the beginning.

**Alfa Laval**
The order quantity is evaluated with help of the Wilson’s formula. As a maximum they only buy for half-year consumption. (unless the supplier has a minimum quantity that they have to buy, in those cases they buy it anyway.)

**Atlas Copco**
When the order quantity should be decided Atlas Copco in Örebro uses their forecasting support system, SCC. The system calculate the order quantity based on the volume value and picking frequency for a given service level. There are the demand history and forecast of sales that are the foundation for the order quantity.

**Bombardier**
At one of the warehouses at Bombardier it is the lead times and the costs that control the order quantity. The amount that is purchased is supposed to cover one year’s demand. They do a check-up quarterly. For the other warehouse the quantity depends on how many they sell.
Volvo
This is based on the individual articles volume value and the reception of the goods total capacity through iterative simulations.

5.3.1. DISCUSSION
Wilson’s formula is based on the fact that the order demand is continuous. This makes it hard to implement on the aftermarket since the aftermarket handles such a variation in demand. However, the method could be implemented on a group that contains the most frequent articles, if the company has divided their articles into groups. Alfa Laval is using this method on all of their articles but they only buy a maximum of half-year consumption at a time.

The EOQ method is a bit complicated and because it involves the Wilson’s formula it also requires a continuous demand, which is not possible on all articles within the aftermarket. One positive factor, however, is that this method concerns both order quantity and safety stock. When a method concerns different factors within the supply chain it often leads to a better result and unnecessary work will be eliminated.

The estimated period requirements method can be used in two ways, experience or economic correct numbers. There exist both positive and negative factors if the experience is chosen as evaluation base. The positive is that the experience has given the company the opportunity to know when a change in the market is about to happen and they are able to change the order quantity so it will fit the new demand. The negative factor of using the experience is that the order quantity can be false because the calculation is not based on correct numbers, which sometime is to prefer. The best is to combine these two; use the experience to choose which strategy is best for the own company and their situation. In this method the order quantity changes when the demand change and the method look at the demand during a period. The quantity of an order should cover that period. How long the period is depends on the company and article.

There is a similar method to the estimated period requirements, it is called economic period requirements. The difference is the calculation, the economic period requirement method calculates with both ordering cost and inventory cost. It is to prefer that the calculations include as many costs that are affecting the inventory as possible in order to reach an optimized order quantity.

In the Silver- Meal’s method the order quantity is optimal when the ordering cost and inventory cost are equal. This method is useful when the demand is known, it does not need to be continuous but it has to be known. This is the reason why this method is to prefer rather than Wilson’s formula where the demand needs to be continuous.

In order to get a continuous demand, so the decision of the order quantity will be executed easier, it is helpful to solve the variation problem. If the demand is continuous there are more methods to choose in order to improve the flexibility. In the theory, 3.3, four different flexibilities are presented; product-, product mix-, volume- and delivery flexibility. The only one that cannot be implemented on the aftermarket is the product mix flexibility, because it is affected by the production. The product- and volume flexibility can be used if the collaboration is good between the company and the supplier who produce the articles. It is only the delivery flexibility that ABB OC SE can improve by themselves without collaboration with another party. They can improve it by having a higher amount in inventory so when the demand increases they have the article to deliver directly from their inventory. If ABB OC SE should solve the variation problem by doing this, they will get increased
inventory cost and since they work with the aftermarket that solution is not suitable. The risk that the articles lie to long in inventory, possible all the way to scrapping, is too high. It is better to have a small inventory and handle the variation in a different way. If the company works with a method that has a fixed order quantity the changes in demand are more difficult to handle, so to get the optimal solution of the variation problem, it is recommended to improve the predictability by developing a method with both the suppliers and the customers so the factors that are important will surface and the method will work.

A positive factor with Silver-Meal´s method is that it calculates which amount of an article that has the lowest costs. The demand needs to be known but it can vary every month and the purchasing happens when the cost is lowest. Purchasing a certain amount over several periods at once, leads to higher inventory cost so at first sight this method can be seen as a wasteful one but because the ordering cost is minimal the cost is only divided differently. Since this project is made from an aftermarket perspective it is desirable to have a low inventory because it is difficult to predict the demand and the company does not want to have too much in inventory. It is better to purchase small amount of articles several times then the opposite, to purchase many articles a few times. So this method is not optimal within the aftermarket.

The last method to choose from is the LTC method, this method is similar to the Silver-Meal method but not completely. The order quantity is optimal when the order- and inventory costs are equal, exactly as the Silver-Meal method but in this method the total cost should be minimized during the whole time and not the total cost in a period. A new order should be placed in the first period that the inventory cost exceeds the ordering cost, thus when the inventory get more expensive than it is to order new articles. In that way the cost is minimal, the order quantity needs to be a sufficient amount to cover the replenishment time.

Atlas Copco in Örebro decide their order quantity through their business system, SCC and that system base the decisions on volume value and picking frequency. It uses history and forecast so the order quantity should be as optimal as possible. Bombardier also bases their order quantity on history but they do it manually. To do it manually only a few articles is to prefer. If ABB should do it manually the result would not be satisfying because they have too many articles in inventory. If they would have only a few articles in inventory and the rest as order bound they could do it manually, in theory. The recommendation is to find a method that calculates the order quantity because the demand changes. It is easier to rely on a method than the uncertainty, which lies in the human nature. It is better for the employees to have a structured work plan and it is important that they feel that the method is working and that they are able to rely on it. Volume value and the capacity of receiving goods are something that Volvo use in order to decide the order quantity, the communication between the receiving- and purchase department need to be good. The purchaser need to know for sure that the receiving have the capacity to receive a new order and not rely entirely on the system. Of course the employees should be able to rely on the system but sometime it fails and then it is positive to already have a good communication with each other. If the good communication exits it is possible to discover the lacks in the system before it makes any damage. Development of the inventory is another reason for the department to have good communication.
5.4. DIMENSIONING SAFETY STOCK
The section 3.3.4 in the theory describes roughly four methods to dimensioning the safety stock. One of them is called dimension to service level and consists of three sub-methods, one of these handles the uncertainty in demand, another handles lead time and the third one is a combination of the two and concerns the possibility to have uncertainty in both demand and lead time.

Another method is called “Safety stock based on cost optimization”. This method decides the safety stock by balancing the shortage cost and the inventory cost.

A third method is called Number of days of demand. This is one of the simplest methods and also the most common. The safety stock should be equal to a number of day’s average demand. The last method is called Percent of the demand during lead time. This method is about dimension the safety stock as a percentage of the demand during the lead time, it is also called a proportionality approach. The safety stock calculation is based on the demand during a number of days since the safety stock size can be expressed as the percentage multiply by the lead time in terms of days multiply by the average demand per day.

Alfa Laval
The most frequent articles (that stands for 80% of the order lines) get their safety stock calculated by the following formula:

\[
\text{Safety stock} = \text{Safety factor} \times 1.25 \times \text{MAD} \times \sqrt{\text{lead time}}
\]

The safety factor is decided due to the service level
MAD= Variation in consumption

For the middle- and low frequent articles the safety stock is decided with the help of the Poisson table (not normally distributed).

Atlas Copco
In order to dimension the safety stock it is the SCC system that make the decisions, just like when the order quantity and order points are decided. Even here the decision is based on the demand history and forecast of sales. All available components exist in a safety inventory, both stocked- and order bound items.

Bombardier
In one of the warehouses they do not use a safety stock but they use a Two bin system 3.3.4.4, in the other warehouse they do not use any safety stock at all.

Volvo
At Volvo the safety stock is based on the lead time from the supplier, consumption and variations in consumption. Generally they strive to have as high service level as possible for low-cost articles and critical articles and therefore have a bigger safety stock for those articles.

5.4.1. DISCUSSION
The first method in order to decide the dimension of the safety stock is dimension to service level. It is positive that this method, in turn, has several methods, it has both uncertainty in demand, uncertainty in lead time and a combination of those two. If ABB OC SE should implement this method they would have the most use of the uncertainty in demand, at least in the beginning. They should start with an easy method so it will be implemented in their way
of working and when they have find a structured and comfortable way of working with the method they can start to use a more complex method if that will reach a more optimal inventory. So from the beginning ABB OC SE should use the uncertainty in demand since the combined is more complex. The most frequent articles may not need this method because the demand is more certain. The articles that have an uncertain demand fit this method perfect. If there are articles that are uncertain in both the demand and lead time the complex formula needs to be used but it is recommended to try to improve the safety stock without it in the beginning. If the demand and lead time is not normally distributed it is not possible to use this method.

Information during a long time period and caution are needed in order to reach the optimized safety stock. It is positive that the method points out that the result is only a guideline, it can be necessary to change it manually sometimes. A follow-up of the calculations is important so that all the contributing factors are included. Alfa Laval does also use calculations in order to improve the safety stock but they have developed the formula by themselves so it will fit their own company and their way of working. It is 80% of the most frequent articles safety stock that are calculated with that formula, 4.2.1. The formula is based on service level and this method has an obvious connection with the goal that Alfa Laval wants to reach. For the articles that have a low or mid-frequent demand they are using the Poisson table.

Cost optimization is another method that can be used in order to dimension the safety stock. The inventory increases the inventory cost but this method balances the inventory cost and shortage cost. The optimal should be to minimize both costs. It is a simple method to use and the information that is needed in order to use it is easily available. The number of days of demand is a different method, which points out the fact that it is important that different articles have different service level. That is a positive factor with this method; if the demand is higher the safety stock should be higher as well. This method is the one that most companies are using today. The percent of the demand method is complicated and the possibility to get confused when to get an understanding of it is large. There are no guidelines of which percentage to use so it is better to use a method with clear guidelines.

Atlas Copco dimension their safety stock in their business system, SCC, it is based on history and forecast. All of their articles, even the order bound exist in the safety stock. This can be positive if something should happen, for example that the article gets delayed from the supplier. Then if they have the article in safety stock they would not have to worry that much because they can use the safety stocked item to send to the customer. A negative factor is that if all articles exist in safety stock the inventory costs increases and the articles will take up unnecessary space, especially at the company Atlas Copco and Volvo where the articles are large. Atlas Copco has all their articles in safety stock, Bombardier work the opposite, they do not have a safety stock at all. The reason for that is that they do not have the space for it. Instead they use Two bin system, 3.3.4.4., where bin A can be seen as a safety stock. Volvo bases their safety stock on lead time and consumption. They want to have a high service level on the low-cost- and critical articles so the safety stock on those articles is higher. It is positive to have different percentage levels on the safety stock but it is not necessary to have the low-cost articles in safety stock if the demand is not frequent.

5.5. CONCLUSION OF ANALYSIS
By analyzing the information from the theory and the benchmarking, some assumptions have been made and recommendations for ABB OC SE have begun to form. These recommendations will be presented in the next chapter.
Some of the assumptions that have been made are that a form of categorization is necessary. This will make it easier for a company to use different strategies for different categories, which can lead to better management improvements opportunities.

The analysis has also shown that strategies for order point and order quantity are similar because some of the different methods for order point depend on the order quantity and vice versa.

This stands for the safety stock and the order quantity as well, what kind of order quantity-strategy the company has decides which strategy that is suitable for the safety stock.

Questions that need to be taken into consideration when constructing recommendations for ABB OC SE are:

- What kind of categorization is suitable for ABB OC SE?
- Should the order quantity be changed according to the category that the article is in, not every time it is purchased?
- Is it necessary to have a safety stock for all of the stocked items?
- Since these aspects affect each other, is it possible to have different strategies for different categories?
- Should the order point be decided due to the categories, or should all the articles order point be decided by the same method?
6. RESULT

A final proposal of the four questions will be presented and explained in order for ABB to implement it.

The goal with this thesis and the result that is desired, is to find strategies and methods that give ABB OC SE the opportunity to work in a standardized way. The methods today differ from article to article and are not documented in a good way. This result is supposed to make the work easier to follow and it will also be easier to submit the work to a new coworker.

The recommendations are not supposed to be all that complex and heavy but to be seen as an improvement that is easy to implement. When and if the implementation has run smoothly, then more complex steps are available to use.

6.1. METHODS DO DECIDE WHETHER TO HAVE STOCKED- OR ORDER BOUND ITEMS

In order to decide whether an article should be in inventory or order bound the theory has presented categorizations, calculations and methods that are mostly used in Swedish companies. The calculation strategies seem a bit too complex and time consuming so the result that will be presented is based on the categorization and the most common method (order lines).

As it is now ABB OC SE are using one way of categorizing their products, the life cycle categorization. This is a good way to work with the products in order to know the basis of where in the demand chain a product is stated. It also gives the customers a clear view of what products and articles are available and their rights according to the warranty.

But in order to manage the inventory and to find an optimal purchasing strategy, there is a need for better and more structured categorization. The recommendation is to make a categorization according to the ABC analysis and adapt it so that it fits the ABB goals. This categorization is presented in three steps below:

1. The first step is to decide which products or articles that should be in inventory and which should not. The different categories can be called Inventory Items (II) and Order bound Items (OI). The analysis should be based on frequency (order lines) and critical articles (articles that are needed to make a product work, without these articles the product is useless). It is also important to avoid articles that have an expiration date in inventory, since there is a risk that these articles will be disposed before they are needed. This is of course something that is going to change over time, articles that are high frequent one month could be low frequent another month. Therefore a reevaluation of the II- and OI categories is necessary and should occur once a month or every other month like Alfa Laval and Atlas Copco.

The most frequent articles, the ones that should be in the category II, should be decided to meet a restriction or limitation. This could be maximum amount of articles in inventory like Bombardier, or a percentage like Alfa Laval, they have decided that 95 % of all order lines should be in inventory.

The knowledge of where to draw this line is something that the purchasers have. So this is a decision that only they are able to make. A recommendation is to have a percentage not a maximum amount. This because of the fact that most of the articles are small and do not take up that much space and to have a maximum amount could be distracting since the purchasers sometimes have to buy a large batch of one article that, for example, is about to reach its end.
of production, or if the knowledge of an increased demand comes to the purchaser's realization.

For the OI the focus must lie on improving the communication with customers and suppliers in order to reduce the lead times and forecast the demand.

2. After categorizing which articles that should be in inventory and which articles that should be order bound a more thoroughly categorization is done in order to manage the inventory. This categorization is done on the II and the categories are called sub-categories, according to the ABC analysis.

Alfa Laval has chosen to use five sub-categories but in order to facilitate the implementation at ABB OC SE three sub-categories are enough. When this way of working stands as a routine ABB OC SE can evaluate if more sub-categories are necessary and should be developed.

The three sub-categories within II are called High-, Medium- and Low Frequency (HF, MF and LF) and exist as a help to decide how many of the different articles that should be in inventory. So here an evaluation is done exactly as in the first step but here it is done within the II category in order to clarify it additionally. The HF, MF and LF categories are supposed to use strategies that fit their different frequency level and also meet different goals.

3. The different strategies for each sub-category, order point - order quantity - safety stock, will be discussed in the following three sections. In order to facilitate the categorization and to know which articles that should be placed in the different groups, different percentages can be set up as guidelines. For example; let HF stand for 60% of the order lines within II, MF for 30% and LF for 10%.

Which goals a company, in this case ABB OC SE, sets up can differ and depends on what they want to achieve. The recommendation is to measure the goal in delivery dependability, which Alfa Laval makes in the current situation. When this is implemented it is important to know how to calculate the delivery dependability. Through the benchmarking, information on how four different companies calculate that factor has been collected. Alfa Laval calculates their delivery dependability from the goods are picked, packed and shipped. How long it takes for the customer to receive the goods is compared to the delivery time that Alfa Laval had promised. Atlas Copco measures the delivery dependability by comparing how many orders that are rightly delivered to customer. Bombardier only calculates the delivery dependability on finished repaired products. They use a start- and end date. Volvo’s way of calculating the delivery dependability is information that the contact person at Volvo would not share.

To deliver the goods in the right time to the customers are important and it is equally important to deliver the right articles and articles that not are damage. The recommendation is to calculate the delivery dependability from the order has been received to that the customer has get the right articles, the right amount and without any damage.

6.2. ORDER POINT SYSTEMS
The theory, 3.3.2., presents five different strategies in order to decide the order point. The Kanban strategy is not optimal when it comes to ABB OC SE’s inventory management. This because it requires a continuous demand at all times, which is impossible to have at the aftermarket and it also requires a closer contact with the warehouse, in this case CSN.
The contact with CSN is something that the Two bin system also needs in order to work properly and with the fact that this master thesis is not supposed to change the routines at CSN, the two bins also becomes a non-option.

The (s,Q)-, (s,S) - and (s,Q-p) system is not as well defined as it needs to be in order to find a structured and balanced strategy for ABB OC SE. It does not provide the information and guidelines that are necessary.

For ABB OC SE the recommendation is to use different strategies for the different sub-categories. These because of the fact that the articles in HF should be frequent enough to use methods for continuous demand, where a forecast can be done with a high certainty. Atlas Copco bases their forecast of 12 months history. The recommendation is to base the forecast on at least 12 months, a longer time period will give a more accurate forecast. By doing a forecast based on 12 months it is possible to see the changes in the demand so it is possible to forecast if an article should change category ahead. For HF the Run-out time planning is a suitable alternative. Here the order point is calculated so that the demand can cover the replenishment time. This requires a forecast, which is not possible to have with the MF and LF articles. The Run-out time strategy is also to prefer due to the fact that it considers a form of safety time. This is necessary since the aftermarket, which ABB OC SE handles, is such an uncertain market and variations and other problems can occur along the way. The recommendation is to plan for a new purchase if the run-out time minus the safety time is less than the replacement time.

When an accurate forecast is not possible to make, which is the case with the MF and LF articles, the recommendation is to, instead of the Run-out time planning, use the Consumable replacement system. This system suggests that the purchase should occur at fixed delivery dates and letting the order quantity vary, instead of having fixed order quantities. It is also to recommend when many articles are purchased from the same supplier, with this method it will reduce the tied up capital and get increased flexibility as a result. To coordinate the transport from different suppliers will also reduce the costs.

As an alternative to this, another recommendation for ABB OC SE is to use one strategy for all of the sub-categories. Alfa Laval are doing this and they want a delivery when their ATP (Available to Promise) is lower than the safety stock, 4.2.1.

\[
ATP = \text{Onhandbalance} + \text{Outstandingpurchaseorders} - \text{Outstandingcustomerandmanufacturingorders} - \text{forecast}
\]

This calculates what ATP is at the lead-time, if the lead-time is 10 days it compares the ATP 10 days ahead with the safety stock. The purchase order is in that case created 10 days before the ATP at the lead-time is below the safety stock.

Another company that is basing their order point calculations on the safety stock is Volvo.

These methods should be implemented in the business system so when an order point is reached a visual sign appear and the purchaser know that it is time to put a new order. In this way the manual work will be decreased and more structured.

6.3. METHODS TO DECIDE ORDER QUANTITY
The recommendation when it comes to the order quantity is to use different strategies for the different sub-categories as for the order point. When it comes to the HF articles, Wilson’s
formula is to prefer. This is a formula that ABB OC SE is currently using in some areas and it is suitable to use on a continuous demand.

Since Wilson’s formula is already implemented at ABB OC SE this will not be a big change. The employees already have the knowledge and can handle the formula but as said before, this is only recommended for the HF category.

For the MF and LF the decision has already been made to use consumable replacement system for the order point. This system can work together with the LTC system, 3.3.3.2.4., which is also based on fixed order points. Here the purchaser calculates when the orders should be placed over, for example, a year. The order quantity is then supposed to cover the months in between to order points. How many articles that are needed during one month are based on history.

The problem remains with the suppliers that demands fixed order quantities. This is not such a big problem with HF articles, since these will be consumed anyway. For the MF and LF articles it can be a problem. If that item is needed from a supplier that forces them to buy 15; the remaining 14 articles will then lie in inventory and tie up both space and costs. The recommendation here is to either rethink to see if this article should be order bound instead, or try to find a different supplier that can offer another deal.

6.4. DIMENSIONING SAFETY STOCK

A safety stock would not be necessary if everything always went as planned and no conditions were to be changed but in real life that is very unlikely so it is necessary to handle a safety factor. This is also an important factor when it comes to the aftermarket, where nothing is certain.

Customers demand is not always continuous and the delivery from a supplier can be delayed. A safety stock is used when something goes wrong. By using the safety stock the company has the possibility to deliver to their customers without any disturbance.

Also in this case the recommendation is to use different strategies for different sub-categories. For the MF and LF articles, the method called Dimension to service level, 3.3.4.1., is to prefer. Mostly because it handles uncertainty in demand but also since it covers uncertainty in lead time. The formulas are clear and easily explained and can help the purchase planner to be prepared against problems.

The Dimension to service level- system could, if the company wants to, also be applied on the HF articles. An easy way out if they prefer to have the same strategy for all of the sub-categories. In order to improve the inventory management additionally, which is the goal, the recommendation is to use the method that is called Safety stock based on cost optimization on the HF articles.

This because of the fact that these articles most likely has a continuous demand and do not require any special calculations. Instead the recommendation is to optimize the costs where it is possible, which in this case is with the HF articles.
7. CONCLUSION

In order to continue to improve the management of the inventory it is recommended that further studies are to be done. As it is now ABB OC SE will implement the methods that are recommended through this thesis and the result will be a more optimal inventory but in order to reach the optimal it is possible which other methods that not are presented here fit their organization better. One recommendation in this thesis is to use one method for order point and one for the order quantity (per group) but these two factors affect each other so ABB OC SE should evaluate if there are a way to combined them in order to reach the goal, an improved inventory management. ABB OC SE should also evaluate if they need to have a safety stock on every article that is an inventory item, or if they only should have the most critical items there. Critical means the items which a product could not function without, or has such long lead times so that the customer would be suffering.

In the discussion a part is being discussed about a statement that the theory points out, that the articles should not change the group so often. The purchasers risk of losing the knowledge of where the article is located. Fortunately, this is no problem for ABB OC SE because the aftermarket is a slow moving market so the article will not change the group too often. Even if the market had been moving faster it would not have been a problem anyway because ABB OC SE have too many articles available for the customers so it would be difficult, almost impossible to keep track on every article.

ABB OC SE should develop their categorization together with their customers and suppliers because if they do, they will get the knowledge of how flexible the suppliers are and which articles that are critical to the customers. This is time consuming and difficult because of the amount of both customers and suppliers but it is recommended to do it any way since the result will improve in the long run. It is also recommended to start collaborate with other ABB divisions around the world that handles the aftermarket in order to share both problems and solutions so that the methods that are used are optimal for the organization.

Another recommendation for ABB OC SE is to contact Stig-Arne Mattsson for more information and support. He is an author and teacher in this particular subject and taking part of his information could be helpful if something is unclear or uncertain.
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9. APPENDICES

9.1. INTERVIEW QUESTIONS

How do you handle your warehouse operations today?

- Number of articles?
- Are these categorized in any way?
- How did you come up with this categorization strategy?
- What factors decide if an article should be in inventory or order bound?

Can you explain the aftermarket?

- Is this a big part of your organization?

What is your strategy?

- How did you come up with the strategy?
- Why?
- How long have you been working with the strategy and have you seen any improvements?

In what way are you working with the issue of managing the inventory? (aftermarket)

- Customers?
- OD? (Operations development)

Most common problems?

- How do you work to solve these problems?

What is the average turnover in your inventory?

- Are articles being held in inventory for longer period of times?
- Risks with articles that stops being produced?
  - Has this happened?
  - What is done to fix the problem?

Do you store any information about the customers?

- Why is that information important for you?
- Market research?
- Are the customers divided into different segments?
- Do you have different strategies for different customers?

Improvement work

- How do you work with this?
- What people are working with this?
- How often?
- Why?
Externalization of the aftermarket?
   o Pros and cons?

Have you been noticing any decrease in the aftermarkets spare parts?
   o Is this because of pirate copies?
9.2. **COMPLEMENTING INTERVIEW QUESTIONS**

- How do you decide if an article should be in inventory or order bound?
- How do you decide the order point
- How do you decide the order quantity?
- How is the safety stock dimensioned?
- How do you calculate the delivery dependability?
Röda tråden

Strategi - inriktning

- Våra tre huvudinriktningar för kostnadsmedveten tillväxt
  1. Effektiva arbetsmetoder
  2. Kostnadsfokusering
  3. Attraktiv inköpsfunktion

Varför – Effektiva arbetsmetoder

- Effektivisering av vår verksamhet är inte ett val det är en förutsättning för att säkerställa lönsamhet, tillväxt och affärer.
- Frigöra tid för utveckling av verksamheten för att kunna optimera våra processer samt möta kundernas och uppdragsgivares nya önskemål och krav.
- Uppmuntra idérikedom som genererar en optimering av våra rutiner så att vi inte fastnar i föräldrade arbetsmetoder.
- Ständigt förbättra resultatet av VU-arbetet och använda den etablerade strukturen som vi har byggt upp inom LogC.
SWOT - Effektiva arbetsmetoder

- **Styrkor (bibehålla)**
  - Har ABB hatt
  - Flexible
  - Koll på processen
  - Väl dokumenterat
  - Arbetar med ständiga förbättringar
  - Mottagliga för förändringar

- **Svagheter (utveckla)**
  - Lagerbindning
  - Lagerplanering
  - Omständiga system
  - Backup (personal)
  - Många produktområden
  - Utveckla kommunikation teknik/köp
  - Ej likformigt arbetsätt mellan inkopare
  - Västerås - Malmö – ett LCM
  - Ingen utbildning

- **Möjligheter (tillvara)**
  - Jobbar i ett system (SAP)
  - Leverantörsansvar
  - Aktiv kostnadsbesparing
  - Systemkunskap
  - Lära av andra LBU:er
  - Systemförändring

- **Hot (hantera)**
  - Grus i integrationen
  - Färre personal
  - Material förstoring
  - LCM

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KFF – kritiska framgångs faktorer – vad är kritiskt för oss

- **KFF – Effektiva arbetsmetoder**
  - Vi har ett systemstöd som stödjer vår affärsmodell
  - Säkerställer att vi kan täcka varandras arbetsområden
  - LCM
    - Många artiklar till Logistics Center
    - Skrota/avveckla i tid
  - Vi arbetar enhetligt inom PA – gemensam inköpsprocess
  - Vi har produktkunskap
  - Vi nyttjar vårt systemstöd fullt ut
Mål - Effektiva arbetsmetoder

- CoPQ – jobba med områden som genererar mer än 300°SEK i kostnad

Varför – Kostnadsfokusering

- "Vi kan inte växa om vi inte hanterar våra kostnader". Joe Hogan

- Vi ska öka vår konkurrenskraft genom tillgänglighet och tillväxt

- Med rätt lager, en hög servicegrad samt en god leverantörsrelation ökar vi värdet för kunden.

- Genom vårt fokus på lägre totalkostnad bidrar vi till att öka ABBs lönsamhet.

SWOT - Kostnadsfokusering

**Styrkor (bibehälda)**
- Cost avoidance
- Fraktarbete

**Möjligheter (tillvarata)**
- Mutilppel source
- Konstatera volym
- Frakter
- Konkurrensutsatta leverantörer
- Lagerhållning
- Priset/or / kontrakt
- JOM
- Autokop
- OTD
- Leverantörssamverkan
- Nya leverantörer
- Produkter
- Fjärr

**Svagheter (utveckla)**
- Effektivare lagerplanering
- Produktion skap
- Rätt leverantör
- Effektiv inköpsprocess
- Visualisera bessningar
- OpEX
- Bosparringsplan

**Hot (hantera)**
- Lågvolym
- LCM - LTB / obsolete nivå
- Leverantör försvar
- Singel source
- Omvärldsfaktor – force major
- Dyrrh frakter – kunden ändrar köpbeteende
KFF – kritiska framgångs faktorer – vad är kritiskt för oss

- KFF – Kostnadsfokusering
  - Besparingsplan
  - Visualisering av besparingar
  - Leverantörssamverkan
  - Förhandling
  - Lagerhållning

Mål - Kostnadsfokusering

5%

Varför - Attraktiv inköpsfunktion

- Omvärlden förändras! För att hantera detta måste vi utvecklas och känna oss bekväma med förändringen.
- Ett bra arbetsklimat är en förutsättning för att lyckas.
- Personlig utvecklings plan.
- Allas individuella förmåga, kunskap, skicklighet, erfarenhet, engagemang och idérikedom är avgörande för LogC’s framgång
- Det är vår samlade kompetens som gör det möjligt för LogC att vara en mycket lönsam och växande verksamhet
- Med ett bra ledarskap skapar vi förutsättningar för LogC’s medarbetare och gör oss till en attraktiv arbetsgivare
SWOT - Attraktiv inköpsfunktion

Styrkor (bilbehålla)
- Bra grupp
- Bra chef
- Vi har viljan
- Olika bakgrunder
- Transchikunskap

Svagheter (utveckla)
- Mycket administrativt
- Våra rättigheterimandat
- Säkrar inköpsutbildning
- Kompetensgap
- Hur värderas inköp i LC:s organisation

Möjligheter (tillvarata)
- Breddad kompetens
- Dubbla roller
- Engagemang
- QCS service center

Hot (hantera)
- Nedskärningar
- Flytt av produktområden
- Odefinerad / olydig / ovisst roll i LC:s framtid
- Varje individs värde för LC

KFF – kritiska framgångs faktorer – vad är kritiskt för oss

- KFF – Attraktiv Inköpsfunktion
  - Trivsel på jobbet
  - Öppen för förändring
  - Ledningen uppmuntrar till utveckling
  - Kompetens mappning – individuell utvecklingsplan
  - Öppen dialog mellan avdelningarna
  - Delaktighet -> värde -> ”jag är viktig”
  - Vi vet vårat mandat
  - Breddad kompetens
Mål - Attraktiv inköpsfunktion

- Alla inköpare ska ha en individuell utvecklingsplan 2011-Q4
- Folk söker jobb hos oss.

Mål 2011

1. Effektiva arbetsmetoder
2. Kostnadsfokusering
3. Attraktiv inköpsfunktion

Målbild 2014

1. Effektiva arbetsmetoder
   - Automatköp – vi köper 100% som finns på kontrakterad lagerartikel med automatköp.
   - N kontrakt/prislistor.
2. Kostnadsfokusering
   - 5% årligen på direkt/indirekt mtrl och frakter
3. Attraktiv inköpsfunktion
   - Vi har enbart certifierade inköpare enligt SILF alt ABB.
   - Alla har en individuell kompetensplan kopplad till apprasial.
   - Projektkompetens – vi har kompetens och driver minst ett projekt årligen.
Active phase
A product is ACTIVE once it has been released for sale. It is actively marketed for new installations and for Sentinel use cases. It is maintained normally and is contained in the respective sales price books.

The length of time for Active classification is dependent on market conditions, technology advances and hardware and software component availability to ABB. ABB’s intent is to develop and market products that support upgrade with minimal impact to the customer’s process.

Classic phase
A product will become CLASSIC when Product Management makes a decision to remove the product from active sales for new installations. The product maintenance is still the responsibility of Product Management and Development. Typical product maintenance in this phase is limited to product changes due to vendor obsolescence of components, or any serious latent problems that have a major impact on product operation (business critical problems).

System 800xA Product Management will issue a notice to all sales channels that the product is “Removed from Active Sale” and will enter the Classic phase. This notice will be sent at least 12 months in advance of the transition. This announcement may be bypassed if a product is replaced by an exact form, fit and function upgrade. The sales channels have the responsibility to communicate this action to customers within reasonable time, to provide at least 6-month time to the customers.

For hardware products Product Management issues a notice to all sales channels when the product is subject to LAST BUY. This notice is sent six months in advance of the transition but may have to be shorter for reasons such as short notification from a vendor. LAST BUY is open to end customers for 12 months and is immediately followed by VOLUME MANUFACTURING END. At this point all support and manufacturing by the System 800xA product organization is ended.

Limited phase
A product enters the LIMITED phase after the VOLUME MANUFACTURING END. At this point product responsibility is transferred to the Service organization (Logistics Center) and product support is now performed solely by the Service organization. Service will work with Product Management to determine what types of internal documentation or other items are needed for long-term support and decide the transfer arrangements.

The support in this phase is typically limited to field service, workshop repair and the sale of refurbished spare parts. Technical phone and remote support may also be available but not backed up by Level 4.

All of these services are on a best effort basis and provided as long as it is both technically and commercially feasible to do so. The length of this support phase may be enhanced by the active return of valuable hardware.
A flexible Classic to Limited transition is used where the volume of the actual hardware part will determine the transition point in time. The combined Classic and Limited support time is guaranteed for 10 years from when the product was made classic. Exceptions to this may occur if software and hardware components or technologies are no longer economically available to ABB, at which point an upgrade path to a current product offering will be supported.

Obsolet
A product enters the OBSOLETE phase when ABB for technical or commercial reason no longer is able to guarantee the support of the product. This decision is made by Product Management after review with the selling channels responsible for the majority of the remaining installed base. However, the Service organization may still be able to support the product, or parts of it, on a best effort basis, limited to available parts and component inventory.

A notice will be sent to all sales channels at least 6 months prior to the start of the Obsolete phase.