Analysis and improvement of the production planning at Willo AB

– Through development of a classification model

David Sannéus

Supervisor: Martin Kylinger
Examiner: Veronica Lindström
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David Sannéus
Executive summary

Title: Analysis and improvement of the production planning at Willo AB - Through development of a classification model

Background and problem description:
Companies in the manufacturing industry always strive to find ways to improve. One of the main areas for improvements is the process of planning the production. Willo AB is a family owned subcontractor located in Växjö, Sweden, who specializes in producing precision parts. Willo has grown over the last years and now fears the present procedures and personnel are in need for additionally support to perform the production planning in a sufficiently good way. High importance is therefore set in structuring a clear process to facilitate the future planning, with the use of product groups and classifications.

Purpose and research objectives:
Study how the current production planning process is conducted at Willo, to map and suggest future improvements. The goal is to develop and present a method for classifying products into different groups. The classifications should facilitate an easier and faster production planning process that can handle more products in the future.

1. Initially map the planning process and identify processes that influence the production plan at Willo.
2. Analyse the identified differences between Willo’s planning focus and time horizons to theoretical literature.
3. Develop a method for classifying products into different groups, which can be used for production planning purposes.
4. Suggest future improvements to Willo with foundation from the presented classification method and identified differences to the literature.

Methodology:
Four phases divides the study; planning phase, data collection phase, analysis phase, and conclusion and recommendations phase. The planning phase consists of a background together with the purpose and goal for the study. Data collection phase include the case study about production planning at Willo and the literature study. The planning at Willo has been studied by using interviews, observations, and internal documents. The analysis phase incorporates the study where Willo’s production planning is compared to the theoretical framework. The analysis led to recommendations to Willo and a further development of some of the suggested improvements presented in the last phase.

Conclusions:
Willo’s production planning process has been described in a process map where potential improvements have been highlighted. Other suggested improvements regarding the operational organization have further been identified and discussed. Development of a classification model has been made, which enable product groups to be formed according to manufactural specifications. Willo can use this model to support decision making during the production planning process, were the new information can facilitate an easier and faster process that can handles more products in the future.
Sammanfattning

Titel:
Analys och förbättring av produktionsplaneringen på Willo AB - Genom utveckling av en klassifikationsmodell

Bakgrund och problembeskrivning:
Företag inom tillverkningsindustrin strävar alltid efter att hitta nya sätt att förbättras på. Ett viktigt område som ofta kan förbättras är processen att planera produktionen. Willo AB är en familjeägd underleverantör beläget i Växjö, Sverige, som ägnar sig åt att producera precisionsoch grafiska produkter. Willo har under de senaste åren vuxit mycket och anser att de nuvarande rutinerna och personalen är i behov av ytterligare stöd för att kunna utföra planeringen på ett lämpligt sätt. Stor vikt läggs därför i att strukturera och analysera produktionen som kan hantera fler produkter i framtiden.

Syfte och forskningsmål:
Studera hur den nuvarande produktionsplaneringsprocessen utförs på Willo, kartlägg och föreslå framtidiga förbättringar. Målet är att utveckla och presentera en metod för att klassificera produkter i olika grupper. Klassificeringarna ska underlätta en enklare och snabbare produktionsplaneringsprocess som kan hantera fler produkter i framtiden.

1. Kartlägg planeringsprocessen och identifiera processer som påverkar produktionsplanen på Willo.
2. Analysera de identifierade skillnaderna mellan Willo’s planeringsprocess och tidshorisonter mot teoretisk litteratur.
3. Utveckla en metod för att klassificera produkter i olika grupper, som sedan kan användas för planering av produktionen.
4. Föreslå framtidiga förbättringar för Willo med utgångspunkt från den presenterade klassificeringsmetoden och identifierade skillnader i förhållande till litteraturen.

Metodologi:

Slutsatser:
Willo’s produktionsplaneringsprocess har blivit beskriven i en processkarta där potentiella förbättringar har lyfts fram. Vidare har andra förbättringsförslag som rör den operativa organisationen identifierats och diskuterats. Utveckling av en klassifikationsmodell har genomförts, vilket gör det möjligt att bilda produktgrupper och formera planeringsrelaterade specifikationer. Willo kan därför använda denna modell till stöd för beslutsfattandet under produktionsplaneringen. Den nya informationen kan därför underlätta en enklare och snabbare process som kan hantera fler produkter i framtiden.
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1. Introduction

An introduction to production planning will be presented in this chapter together with a company description of Willo AB. With these two parts together, a problem description has been formulated. The problem description incorporates the broad spectrum of production planning that the report will address at Willo AB. Furthermore and later presented, are the research objectives needed to fulfil the purpose and scope of the report together with the limitations. Finally, a figure illustrating the structure of the report is also presented.

1.1 Background

This report is a master thesis, which has been conducted at Willo AB in Växjö. The background is divided into two parts, one theoretical background addressing the academic aspects of production planning and one description of the target company, Willo AB including the company history, obstacles, and opportunities related to production planning. Given the foundation generated from the theoretical background and company description, a problem description, purpose and research objectives of this thesis are later introduced.

1.1.1 Theoretical background

Companies in the manufacturing industry always strive to find ways to improve (Vollmann, 2005; Jacobs, et al., 2011) to be able to manufacture at lower costs, produce more with the same resources or in other ways improve the processes (Hill & Hill, 2009). This strive is often referred to as continuous improvements or the Japanese word, “kaizen” that Liker & Meier (2006) writes about. Continuous improvements can help increase the profit margin or generate a larger market share. This continuous strive of making a larger profit is shown in different ways depending on the highlighted area of an organization (Vollmann, 2005; Bergman & Klefsjö, 2008).

For a manufacturing company, as Hill & Hill (2009) writes, the processes of producing is a significant part of the overall costs and therefore often targeted for efficiency improvements. In addition, and reason to why companies try to be as cost effective as possible, is because the customers are paying for the products produced by this department (Bergman & Klefsjö, 2008). This means, a lower cost of manufacturing can open up two new possibilities, first to lower the price of the product that could generate a competitive advantage. Secondly, to keep the price and thereby increase the profit margin (Hill & Hill, 2009).

Furthermore, the manufacturing process can be divided into different focus areas where specific improvements can be investigated and possibly implemented (Bergman & Klefsjö, 2008). One of these focus areas of a manufacturing company is the process of planning the production. Planning the production is as Olhager (2011) describes, one of the basic functions of a manufacturing company, this includes; order prioritization, capacity, and resource allocation. It ensures that resources in form of material, personnel, and equipment are available at the right time in the right place (Olhager, 2011). Production planning can as Olhager (2011) further explains, facilitate a great result if done right, results can be in form of maximized profits, increased flexibility, lower lead-times, and reduced
inventory costs so the goal of the business can be reached. However, production planning can therefore also hinder a company for future growth if a lack of clear directions and priorities are present.

Production planning is further as Vollmann (2005) and Olhager (2011) describes, done in different stages, illustrated in Figure 1. All depending on the time horizon of the specific plan. The main strategic plan decides the overall direction of the business. Further down is the sales and operations planning that have the second longest time aspect reaching about 1-5 years. The master production scheduling representing the yearly plan, material requirements planning representing 2-6 months and lastly the production activity control has the shortest, day to week plan. These plans are all-important and serve different purposes, ranging from strategies and capacity to resources and specific machines needed for a specific product (Jacobs, et al., 2011; Olhager, 2011).

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Figure 1: Planning horizons (Vollmann, 2005; Jacobs, et al. 2011; Olhager, 2011)

For a manufacturing company, it is always important to strive to improve as described in the section above. For a growing manufacturing company this is particularly important, where the production process has to develop to be able to handle an increasing demand (Vollmann, 2005; Jacobs, et al., 2011). The same philosophy is also applicable to the planning process. Therefore, the process of planning the production has to change and develop along with the production, facilitating support for changes with new products, customers and employees (Vollmann, 2005). When this continues, priorities and focus could need a change regarding specific processes. This means, products previously planned in one way, are forced to be planned with a new focus (Olhager, 2011). One example of this phenomenon is a product with low volume and planned with a “Make to order” philosophy. If the volume demand goes up, and the lead-time for producing and shipping is longer than what the customer is willing to wait, the necessary changes can be to alter the planning to a “Make to stock” philosophy, planned with the use of forecasts and Kanban cards (Olhager, 2011). Therefore, if the planning and control process does not develop in the same pace as the rest of the organization, the company can face problems and
eventually outgrow itself, thereby fail to deliver according to their promises (Vollmann, 2005). Therefore, as Wiendahl et al. (2007) writes, it is always important for a manufacturing company to be open and willing to change and adapt to fluctuations in the market and demand. By embracing this philosophy, an enhanced possibility of future growth can be gained (Bergman & Klefsjö, 2008; Jacobs, et al., 2011).

1.1.2 Willo AB

Willo AB is a family owned subcontractor located in Växjö in the county of Småland and is the chosen company for this thesis. Willy Loeffel founded Willo AB in 1956, Willy had a background in watch making industry in Switzerland, and after coming to Sweden to work for an industrial company for a few years, he started his own business. The direction of the business was to be a “tier 1 to 2” supplier, by making precision parts to other companies (Willo, 2015a). This business has since grown and has today around 85 employees and a turnover of 95 million SEK in 2014 (Willo internal documents, 2014). Willo has today the same direction and has become a leading-edge supplying company focusing on metal cutting processing using lathes and mills (Willo, 2015b). The manufacturing floor has a “functional layout” (Olhager, 2011) with separate production departments divided by machine type and form of work performed by the personnel. Willo has no own products, and are therefore dependent on the customer supplying them with a drawing and specifications of the specific component. Willo then check critical parameters to understand the customers’ needs and if specific demands regarding documentation exist. Since Willo specialize in small products with high demands regarding precision, there are often very strict product specifications and requirements to fulfil in order to satisfy the customers. This also incorporates if any changes can be performed to facilitate the production of the product. This classifies Willo as a “tier 1 to 2” supplier of components and small articles sold to customers demanding high precision. In general, the customer later assembles the products produced by Willo with other components to form a complete working product. The products Willo produce are separated, concerning the application field, in three different segments, Willo Medtech, Willo Energy, and Willo Precision (Willo, 2015b).

Willo Medtech focuses on saving lives and on improving the quality of life (Willo, 2015c). In this medical technical field, Willo is working together with the leading companies to develop innovative and refined technical solutions for people in need. The products are used for implants, instruments, diagnostic equipment, and surgical medical treatment methods. For example, Willo has supplied products for the dental industry with prosthesis over the last 25 years. All Medtech products are adapted for use in a clinical environment, which involves strict and specific methods regulated by law of material handling, cleanliness, and quality control (Willo, 2015c).

Willo Energy involves parts for use in power production gained from nuclear, turbines and wind power. All these sub areas demand a strong focus for high precision and surface finish. Additionally, customers in the nuclear power industry, have special requirements for documentation, cleanliness, traceability, and quality control at every stage in the production process. Willo has been supplying the nuclear power industry with complex
components, since the first nuclear plant was constructed in Sweden, therefore established routines to fulfil all these demands are in place (Willo, 2015d).

Willo Precision is about producing the right component with a specific set of specifications for a specific purpose (Willo, 2015e). This is done by the use of advanced parts with different materials and with high focus of accuracy, repeatability, and quality control. Precision is where Willo origins from and have since 1956 produced high qualitative products for aerospace, military, mould tech, food science, among others. Willo adapt the production process in the Precision segment according to the customer demands. Since all customers have different demands regarding product specifications, tolerances, level of documentation, and traceability, which later will mirror the price of the product. In mould tech, self-closing mini-valves to evacuate air from moulds is a main product. These valves are used for tyre manufacturing with high demands regarding traceability. The products are small and have an external diameter from 2 mm and up (Willo, 2015e).

Over the last few years, Willo has increased their turnover by over 10% per year (Swanström, 2015). This has been possible through obtaining the continuous goal of larger market shares in the different segments and with strive for growth by the management team (Willo internal documents, 2014). The effect of increasing turnover has led to newly employed personnel, new machines and a 100% increase of production area over the last year. The new production area constructed during 2014 was finished in January 2015 (Willo, 2015b). This will enable Willo to continue to grow over the coming years without lack of space. Managers at Willo continues to see a bright future, and the continuous strive for 10% growth annually, is still active (Swanström, 2015). The target focus for 2015 has now widened and incorporates other departments in the organization, since the entire organization has to continue to change and develop to make the goal possible (Willo internal documents, 2014).

1.2 Problem background

The increasing demand and the effect, continuous growth, has formed Willo so that new obstacles have surfaced (Grahn, 2015; Lundqvist, 2015). The background to the obstacles is that the extended tasks to manage and update the new customers and new products in the software system have not been prioritized. Instead, a strong focus of producing as much as possible as fast as possible has been selected (Grahn, 2015; Lundqvist, 2015; Smedberg, 2015). This direction has proved positive effect up to this point, with further continuous growth and profit for Willo.

Together with the high requirements of product quality control and cleanliness, and the new increased volumes, little time has been spent on the tasks to manage customers and products with updates in the software system. These administrative tasks of managing new customers and products include updating initial factors calculated when first offering prices to the customer (Willo internal documents, 2014). These factors can be setup times for machines, operation time, and human labour time. Other tasks will also include the flow of manufacturing orders through the plant, prioritization, sequencing, and overlapping. Furthermore, the products are planned for production by using the same procedures as
they were planned before the increase in turnover. The procedure is to plan every product individually, meaning the only difference is now to schedule more products, during the same time as before, for the production planner (Sigvardsson, 2015).

1.3 Problem description

Now Willo fears the present procedures and personnel do not have the time nor the necessary support to perform the production planning in a sufficiently good way (Grahn, 2015). Instead, the personnel are working around the system using notes and other software programs to be able to plan and support the production in the right pace (Sigvardsson, 2015). This way of working is possible at present production and turnover levels but can, if growth continues, quickly change and will eventually be impossible to control with the same procedures (Sigvardsson, 2015).

As Vollmann (2005), Olhager (2011) and Wiendahl et al. (2007) describes, it is important to manage and control changes in demand. Different types of changes can be applied, to be able to handle the fluctuations in demand. The changes to the production either need continuous improvements according to Liker & Meier (2006) or radical transformation explained by Jacobs, et al. (2011) and Vollmann (2005). Independent of the strategy chosen, the main objective is to act according to the changes in demand. Willo now see high importance in structuring a clear process to facilitate the future planning, with the use of product groups and classifications. By identifying similarities, a method could be developed to classify customers and products. The classifications can form groups that simplify the tasks necessary to plan a product for production. Additionally, to facilitate a production planning, which is not depending on a single employee. Therefore, the new process has to enable a future growth and create the possibility to handle more products without losing focus and control of the product flow (Grahn, 2015; Lundqvist, 2015; Sigvardsson, 2015; Smedberg, 2015).

1.4 Purpose and goal

The purpose with this report is to study how the current production planning process is conducted at Willo, to map and suggest future improvements. The goal is to develop and present a method for classifying products into different groups. The classifications should facilitate an easier and faster production planning process that can handle more products in the future.

1.4.1 Research objectives

From the purpose, four research objectives will further specify and point out the aim of this report:

1. Initially map the planning process and identify processes that influence the production plan at Willo.
2. Analyse the identified differences between Willo’s planning focus and time horizons to theoretical literature.
3. Develop a method for classifying products into different groups, which can be used for production planning purposes.
4. Suggest future improvements to Willo regarding the production planning process with foundation from the presented classification method and identified differences to the literature.

1.5 Delimitations
With Willo as the chosen target company, the recommendations are specifically designed for Willo and their processes and cannot directly be transferred to another company without some modifications. In some cases, other companies with similar production and problems can use specific areas of the report, for example the classification model.

The study will include in what sequence and in what machine the orders will be produced in, but it will not go deep into the material and personnel planning aspect of production planning. The only involvement of material and resource planning will be if there are any obvious observations during the study. Otherwise, this area is left for a possible topic to include in another more focused analysis in the future. This includes the optimal order quantities and work in progress, since analysis of these aspects can form a master thesis by themselves.

In the analysis phase have several improvement suggestions been identified. However, only a few of the improvement suggestions have been chosen for further research. This is done to focus the study and leaves therefore suggestions for future studies.

1.6 Structure
The structure of this report starts with an introduction chapter that will give the reader a background to production planning and Willo. The coming chapters of the report will further explain the methodology, theory, and empirical findings gathered from Willo. Further, the analysis will connect and show the differences and similarities between the theory from literature and empirical findings from Willo. A classification model will be developed and tested to group products with similar manufactural specifications together. Lastly, recommendations will show areas of possible improvements that will further help Willo to plan and control their production in the future. The structure of the report illustrated in Figure 2 below,
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<th>Description</th>
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<tr>
<td><strong>Introduction</strong></td>
<td>The chapter presents the background of general production planning together with a company presentation of Willo. A problem description will guide the reader through the purpose and the four research objectives, lastly presented is the delimitations of the study.</td>
</tr>
<tr>
<td><strong>Methodology</strong></td>
<td>The chapter explains the methods used in this study and why. For example, the different parts of how the data collection was performed, together with the reliability, validity, objectivity, and generalizability of the study.</td>
</tr>
<tr>
<td><strong>Theoretical framework</strong></td>
<td>Theories from books and scientific articles regarding production planning, operations, customer relations, among others are here explained.</td>
</tr>
<tr>
<td><strong>Identification of current situation</strong></td>
<td>This chapter includes a company description and a description of Willo's organization, products, and production planning.</td>
</tr>
<tr>
<td><strong>Analysis &amp; mapping results</strong></td>
<td>The chapter presents the results and analysis from the theoretical framework compared to the current situation at Willo. Similarities and differences are highlighted, together with suggested improvements.</td>
</tr>
<tr>
<td><strong>Classification modelling</strong></td>
<td>Some improvement suggestions have been chosen in this chapter were a developed model is presented. The model enable products to be grouped according to manufactural similarities. Which could help Willo in their production planning process.</td>
</tr>
<tr>
<td><strong>Conclusions &amp; recommendations</strong></td>
<td>The chapter includes conclusions and recommendations both from the analysis and mapping and from the classification model, which fulfill the purpose of the research objectives. Lastly presented is a reflection of the research.</td>
</tr>
</tbody>
</table>
2. Methodology

This chapter will present the methodology of the study together with the approach, which has been divided into four phases. Further, the research philosophy, design, and strategy are described, and the process of collecting data in form of observations, interviews, and literature are introduced. The chapter ends with method criticism incorporating a discussion regarding validity, reliability, objectivity, and generalization. With this the quality of the study can be strengthened.

2.1 Method approach

This study is divided into four phases, illustrated in Figure 3, consisting of a planning phase, a data collection phase, analysis phase, and lastly a conclusion and recommendations phase. There are some activities conducted in each phase, which are listed as bullet points in each box. Below each phase will be described together with the activities as circles in more detail.

Figure 3: Description of research approach

2.1.1 Planning phase

During the planning phase, there are three main activities, which will form the base of the study, see Figure 4. The background, first initiating the importance of change for a company, later to introduce the role of production planning for a manufacturing company, both represents the theoretical aspects. Furthermore, the background of Willo including the company, and how they are facing some problems, which has evolved over the last years, is here presented. These two parts are connected to form the purpose and objectives of how to help solve Willo’s problems. The objectives and identification of the task together with the purpose of the report are therefore established. This will illuminate first how Willo plan their production today and secondly to develop a method for
classifying products together, which later can be used for simplifying the production planning. The final activity, are the chosen research methods to facilitate a collection-, analysis-, and conclusion and recommendation phase, which would lead to the fulfilment of the objectives, and by doing so the purpose of the report.

Figure 4: Illustration of the planning phase

2.1.2 Data collection phase

The data collection phase consists of three activities, which are performed under a main production planning project, see Figure 5. In this phase, the theoretical framework will be described, with models and theories that can be linked to the production planning process at Willo, collected from academic peer reviewed journals, and library sources. This creates a basis, so relevant information can be gathered during the empirical collection. Observations, interviews, and documents are gathered through a planning project, which started simultaneously as this study at Willo. The project is constructed of a cross-functional team that stretches from the production manager to operators with the aim of reaching fast and well thought out changes to the production planning process. However, this study functions as a support to the main production planning project and is conducted in parallel. Another important input is the software system, where the quantitative information is collected. The data collection phase with theory and information from software system, group discussions, observations, and interviews, will solve the first research objective.
2.1.3 Analysis phase

The analysis phase consists of three activities, see Figure 6, which will connect, and in an analysis, show important differences and similarities between the theoretical framework and the information gathered in interviews, observations, and documents. This phase will thereby solve the second research objective, resulting in a clear plan of different objectives and in what areas differences and improvement possibilities exist. This phase will also focus on identified similarities found in the collection phase, between customers and products used for development of a method for classify products into different product groups. This will further assess the potential of the planning process, answering the third research objective. Furthermore, this phase will thereby identify the improvement areas, which later will be discussed in the next phase.

Figure 6: Illustration of the analysis phase
2.1.4 Conclusion and recommendations

Finally, presenting conclusion and recommendations, consisting of two activities, see Figure 7. Here an assessment of the different changes that can be made to the production planning process at Willo will be performed, together with the introduction of the product classifications. The analysis in this phase will include conclusions of the improvement suggestions and the effect of the potential solutions, answering the fourth research objective and create conclusions for the study.

![Conclusion and recommendations diagram]

Figure 7: Illustration of the conclusion and recommendation phase

2.2 Research philosophies

The main philosophies that can be used in a research can be classified in solving different problems. Creswell (2014) divides these in four classifications; Positivism, Constructivism, Transformative, and Pragmatism. The most commonly used philosophy for studies similar to this is the positivistic philosophy. This philosophy is according to Creswell (2014), also called the scientific method and usually use existing theory to develop hypotheses to solve problems. Later hypotheses are tested to assess the conformance to theory that can lead to further development (Creswell, 2014). Further explanation to positivism is that the philosophy focuses on the results and not on the researcher since the person should not affect the result in any way, another important aspect is by that the researcher should be able to be swapped for another researcher without changing the result (Patel & Davidson, 2011).

As a comparison, the constructive philosophy however represents the philosophy where the researcher has a larger impact on the results (Creswell, 2014). The constructive philosophy is thereby the counterpart to the positivistic (Creswell, 2014). This philosophy will be used in this study when conducting interviews since interpretation of the answers have to be done. As the interpretation is performed, the conformance will be controlled with the project team members so misunderstandings will be minimized. Further on, the positivistic philosophy will have the largest impact on the study, since the focus will be on...
facts and how different factors influence these (Saunders et al., 2009; Creswell, 2014). The study has a part of the results from a software system giving numerical information which makes it possible to create hypotheses to affect these in different ways, strengthening the positivistic philosophy of the study (Saunders et al., 2009).

2.3 Research approach

The data collection phase has started with a mapping of the current situation of how the production planning is conducted at Willo. This study can be approached in different ways but in general, there are three alternatives. These three are Inductive and deductive and a combination of the two approaches can be used (Creswell, 2014).

The inductive approach represents, as Saunders et al. (2009) write, the workflow of first collect the empirical data and later develop a theory as a result of the gathered data. The deductive approach is however an opposite way of working, in which the development of theory comes first and after which a hypothesis is developed as well as a strategy to test the hypothesis to the theory (Saunders, et al., 2009). Further differences are the deductive approach should have the possibility to, according to Saunders et al. (2009) be measured by the use of facts. This is not the case for inductive research, where more room is left for the researcher to interpret the results. By doing so, the researcher is able to form a theory to build further on. This is also a criticism to the deductive approach where the construction of a theory first does not leave room for alternative solutions (Saunders, et al., 2009).

From this the perception, of using an inductive approach would be preferred when the aim is to understand why something has happened instead of what is happening, which is the deductive counterpart (Saunders, et al., 2009).

For this study, the two approaches are used together in different phases. A deductive approach is used when choosing the subject and theory, since the subject is decided before the research objectives and a hypothesis will be formed in order to solve the specific research objectives (Saunders, et al., 2009). While the inductive approach will be used when the interviews and group meetings are performed, in which the direction of the study can change and adapt according to the outcome as Saunders, et al. (2009) describes it. In general the main task of the study is deductive where a theory is formed and different hypotheses are structured and tested. However, the path of classify customers and products into product groups is an inductive approach, which has developed during the study. Therefore, some hypotheses will be collected and analysed with an inductive approach.

2.4 Process mapping

A process map was developed to visualise the flow of activities and information within a larger task. By doing so, a clear structure of key and sub activities necessary to complete the task will be created. To characterise a process, it has a clear start and end, a customer and a supplier, consist of activities, and it is repeatable (Bergman & Klefsjö 2008). Process mapping can be performed by using different methods, where common methods are flow chart and block diagram. Important for these methods are the ability to clearly point out the activities and depending on the process, where in the organization the activities are
performed. As Bergman & Klefsjö 2008 describes, the knowledge gained by map a process has a large value by itself. Additionally the map also creates a foundation of how the process function today and a starting point of how to improve in the future (Bergman & Klefsjö 2008).

Rentzhog (1998) describe four approaches used when developing a process map, by breaking down the target process into sub processes. The approaches are; Vertical, Phase, Horizontal, and Pareto. Where the vertical focuses on the main process and breaks down each sub process in a chronological order. Phase approach differs where the sub processes are further divided into phases instead of activities. Horizontal approach defines the sub processes first and the activities within, which later are pieced together to form the main process. Pareto approach analyse the process to fine which part that is most important to focus on Rentzhog (1998).

This study will use a combination of a developed flow chart method and information usually found in a block diagram. Furthermore, the addition of input, output, key and sub activities, documents, and person responsible will be described. The process mapping has been performed with a Vertical approach according to Rentzhog (1998) where the main process has been followed and sub processes identified in chronological order. The data collection used for mapping the processes will be described in Chapter 2.7. Additionally a description of how the data was analysed can be found in Chapter 2.8. Symbols used in the process maps are presented in Figure 8 and represent input, output, documents, sub process, activities, or question

Figure 8: Symbols for process mapping

2.5 Research design

There are in general two different types of information. These types of information correspond to the type of design chosen for a research Creswell (2014). These are called quantitative and qualitative designs and are linked to quantitative and qualitative information (Creswell, 2014). However, they represent the two sides of a coin there is also, as Creswell (2014) describes, a possibility to mix the two in the same study.

The two designs thereby explain which type of data the study will collect and use (Creswell, 2013). This data is generated in different ways where the quantitative represents the
measurable data in form of numbers and qualitative data are generated in form of interviews and observations (Bryman, 2002; Creswell, 2013). The quantitative design is preferred when a large amount of data exists and samples can be gathered. Also by the use of statistical tests of significance, is the quantitative design favourable (Creswell, 2014). However, the qualitative design is usually used when observations and interviews are the main resource of information. Because of this, the researcher can gain a broad picture of the research objectives, since it cannot be measured in form of numbers (Creswell, 2014).

When conducting the study at Willo the different phases will have different design approaches. The data collected from the software system is with a quantitative design, since the data consists of closed set of numbers (Creswell, 2014). Furthermore, the interviews and observations will gain a qualitative focus giving the entire study a mix design and approach to the data collection. This mix of design will facilitate the changes that could be made on the study as it carries on meanwhile the structure and goal stays the same (Creswell, 2014).

2.6 Research strategy

Two different research strategies will be presented in this section, since both can be chosen when conducting a research of this type. These are strategies in form of a case study and a survey. Case study is a research strategy when only a single closed system, unit or other isolated occasion is studied (Saunders, et al., 2009). A survey is however characterized by a collection of information under a specific period to gain as broad and complete cover of a subject as possible (Denscombe, 2009). A survey can be conducted in many ways but in general is the information gathering done with interviews, questioners and observations (Denscombe, 2009). One big focus with a survey strategy is to choose a selection of people that can represent the rest of the population, when doing so the results can be generalizable (Patel & Davidson, 2011).

A case study will enable a researcher to focus more deeply into one specific area, resulting in findings that for other strategies could have been overlooked (Denscombe, 2009). This study is normally done in real situations and can thereby be suitable when the researcher aims to see how different factors influence a specific case (Denscombe, 2009).

Furthermore, a case study is suitable for which the aim of the study is to observe one case deeply rather than several cases superficially (Saunders et al., 2009). This approach creates a deeper understanding about what factors that influences that particular case. Meanwhile in a survey, this strategy aims in another direction, since usually a broad, initially review performed by gather information through a mapping of a specific question. A survey study can thereby create a broad picture gained by a sample of people that will represent the entire organization (Denscombe, 2009; Saunders et al., 2009).

The research strategy that best represent this study is case study, since one company is chosen and one particular area of that company. At Willo, this study has a focus of gaining
deep knowledge about how the production planning is conducted to find gaps in the comparison to theoretical literature and to form a strategy in order to close the gaps. The description correlate to the explanation of the case study above, but the research also has an area where a survey is preferred. This area is when interviews are conducted, since the interviews do not cover all of the personnel the results are therefore analysed in accordance with a strategy close related to the definition explained by Patel & Davidson (2011), Denscombe (2009) and Saunders et al. (2009) of a survey. Where the assumption of the sample of interviews corresponds to the entire population is taken.

2.7 Data collection

There are different ways to collect data, where some ways can be classified as quantitative, and others qualitative. As described above this study will incorporate both a quantitative and qualitative designs and will therefore collect data in different ways. Common to most sources of information is the classification as secondary information, meaning that the information is collected from a different source than it origins from (Patel & Davidson, 2011). Usually it is difficult to determine whether the information comes from a primary or secondary source, yet it is an important aspect to consider because the information is considered more reliable the closer to the origin it is collected (Holme & Solvang, 1997). In general, books, articles and other types of literature information are usually seen as secondary information. Interviews in contrast are considered to come directly from the origin hence seen as primary (Patel & Davidson, 2011).

In the study, data collection are performed so secondary sources has been avoided where possible. The interviewed personnel are considered to be primary sources while theories used are considered to be secondary sources (Patel & Davidson, 2011). Specific types of data collection that has been used are; observations, interviews and a literature review with use of books and scientific articles. In Table 1, an explanation shows each method that is used in the study together with a short description.

Table 1: Data collection methods used in the study

<table>
<thead>
<tr>
<th>Data collection method</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observations</td>
<td>Observations have been made every day during the study to understand Willo and the production planning processes within.</td>
</tr>
<tr>
<td>Interviews</td>
<td>Interviews have been held with people affected by the production planning. Giving an understanding of the current situation and the issues Willo have experienced.</td>
</tr>
<tr>
<td>Literature and documents</td>
<td>Literature and documents have been studied in the beginning of the study in parallel to the data collection from Willo.</td>
</tr>
</tbody>
</table>

2.7.1 Observations

An observation can be performed either as a participant or just as an observer (Creswell, 2013). Both are usually documented by making field notes while conducting the observations. The participant observer interacts with the process and activities, this will
eventually make the observer able to sense changes to what is happening instead of only observing it (Saunders et al. 2009). An observation without participation will therefore lack depth in comparison, but this type of data collection has another purpose, where the aim is to see what and how often things occur instead of why (Saunders et al., 2009).

During the study at Willo, the researcher was initially introduced to how the products flow through the production. During this initial observation, notes describing the products and processes were taken, and after the session can be classified as observation without participation according to Saunders et al. (2009). Furthermore, during the study the researcher has since been observing the activities and processes daily. A production planning project was started simultaneously to this study, therefore several observations have been conducted in groups. Activities such as meetings and discussions can be classified as participant observations according to Creswell (2013), making these observations are more beneficial, which lead to a deeper understanding of the organization.

To facilitate a high reliability and validity, the observer has to check and question the collected data so misunderstandings can be minimized (Saunders et al., 2009). In this report, data collections gathered from observation have been controlled to make sure that it is correct and the observed personnel did not intend to twist the truth in any way. Due to this, and that the observations have been collected during a long period have the contribution they have given to this study be seen as trustworthy. Also all the observations can be seen together to form a general perception of the organization without being too subjective.

2.7.2 Interviews

Interviews can be done in different ways but as Doody & Noonan (2013) describes, the research design helps determine the right type of interview to use. In general, as Doody & Noonan (2013) further describes, there are three main types of interviews; structured, unstructured and semi-structured interviews where the structured suggest the quantitative design and unstructured and semi-structured represents the qualitative design. The interviews can also be performed individually or in groups (Saunders et al., 2009).

Structured interviews are characterized by asking the exact same questions in the same order to all interviewees (Doody & Noonan, 2013). Since little room is left to elaborate outside the questions, the structured interview is a time efficient way to collect data. For the same reason it will limit the interviewee´s subjectivity and the results will be easier to analyse (Creswell, 2013). Other aspects are results that lack depth and that it can be seen as a verbal questioner instead of written one (Doody & Noonan, 2013).

Unstructured interviews will usually start with a broad question about the subject and opposite of the structured interview adapt after the interviewee´s responses (Doody & Noonan, 2013). The data collected from unstructured interviews are deeper but the correlations between the results are usually hard to make (Creswell, 2013). Subjective perceptions of the interviewees also has to be considered, unstructured interviews are therefore more time consuming when analysing, compared to structured (Doody & Noonan, 2013).
Semi-structured interviews are most commonly used when a qualitative design has been chosen (Doody & Noonan, 2013). The interviews have predetermined questions similar to a structured interview but the researcher can adapt the questions according to the responses given. The semi-structured interview is thereby a mix between the structured and the unstructured interview, with a flexible touch. Since the results can vary in semi-structured interviews, the analysis can in this case also be time consuming (Doody & Noonan, 2013).

During this study, unstructured interviews have been held in the initial phase of the report. These interviews gave an understanding of the company, products, and processes but also how the production planning was conducted at Willo. In addition, after the problem was described unstructured group interviews were used, gaining a better understanding of the factors influencing the production planning at Willo. Furthermore, several semi-structured interviews have been used to collect subjective knowledge generated by personnel in different positions at Willo. This has been performed after the observations in group during the production planning project meetings, due to the importance of the different individual perceptions. These interviewees, dates, and subjects, can be seen together with the semi-structured interview guide in Appendix 1 & 2 respectively.

2.7.3 Literature and documents

The theoretical data collection has been performed in parallel to the empirical data collection in this study. The literature review has been collected from literature, in form of books and scientific articles to build the theoretical framework on. The sources has been chosen with the aim of finding documents, books or scientific articles that best describe and show the use of a theory. Also important is to minimize secondary sources if possible, as described above, and to be critical to the validity and reliability towards the information. Therefore only peer reviewed scientific articles has been used and books written by known authors in their field. The literature review has been done in order to gain the necessary background knowledge to attack the problem, but also to build the theoretical framework on.

The empirical findings generated from documents and the software program that supports the production planning needs to be viewed critically. Since the frequency of updates and accuracy to reality could vary a lot. This information can also be classified as quantitative and consist most of secondary sources as Patel & Davidson (2011) describes it. All documents and data collected have therefore been verified with responsible personnel before put in the report to make sure the correlation to reality is sufficient.

2.8 Analysis method

Analysis of collected data is performed to highlight patterns and to group information to gain new insights. The method used for analysing data depends on the chosen research design, if the study has a qualitative or quantitative design method (Christensen et al., 2010). A study with a qualitative design demands significant time since the collected data is in form of text, observations, and interviews and will therefore often need interpretation. A qualitative analysis will focus on the big picture and by collecting data, gain an
understanding of a context (Christensen et al., 2010). However, in a quantitative analysis, is it necessary to standardize the results in order to create a base for comparison, where the comparison can be performed by using statistical methods (Christensen et al., 2010).

As described in Chapter 2.5, this study has a mixed research design, however, the data collection gathered from observations, interviews and software program have been analysed in a qualitative approach. To gain further understanding, content analysis is used, which is a method of analysing text and documents in a systematic way (Bryman & Bell 2011). Specifically used is the approach that Bryman & Bell (2011) describe of ethnographic where understanding of the meaning of a content is of significance. This was used because of the qualitative data gathered from the interviews and observations, to understand the meaning of the information and to highlight relevant information. During the observations and interviews notes were taken, which later were compared to find the most accurate information for the specific topic. For example, parts of the information were divided into key and sub activities, later used for the process mapping.

Data collection used in the classification model was generated through both software programs and interviews. This data have been used to form the classification model and will therefore have a similar method of content analysis and ethnographic analysis as described above. Since the important aspects of understanding, the meaning of information, and to highlight relevant targets that Bryman & Bell (2011) explains is significant for the model. The analysis of data and the generation of the model therefore origins from the method of ethnographic content analysis explained here. However, further information of how the classification model is developed is explained in Chapter 6.

### 2.9 Method criticism

In this section, the chosen method will be discussed and criticised to question the trustworthiness of the study, by doing so the relevance of the results can be assessed. There are four aspects of trustworthiness, often discussed in studies similar to this; validity, reliability, objectivity and generalizability (Befring, 1994; Denscombe, 2009).

#### 2.9.1 Validity

Validity relates to the study in a way that it should measure what it was intended to measure, meaning a degree of how and if the results answers the research objectives (Befring, 1994). Therefore, it is important to perform measurements that actually measures what was intended (Befring, 1994).

The validity of this study can be argued to be both high and low. Since the interviews have been performed with a semi-structured strategy, it could lose some validity, due to a lack of standardized fixed questions. In this aspect, the interview guide will help to keep a straight focus on the interviews without losing track of what is important for the study. This will ensure keeping the validity sufficiently high. Regarding the observations, the validity can be regarded to be higher, compared to the interviews, since these have been performed during a longer period and only a small part of the observed information will end up in the report. Therefore, together the interviews and observations can be regarded to have sufficient level of validity and thereby measure what was intended.
2.9.2 Reliability

The reliability describes how trustworthy the collected information is, which means if the researcher can trust that the information given is untampered by the giver (Befring, 1994). The reliability describes furthermore the possibility to reduce errors in the measurements, which can be performed by measuring the same thing more than once, and in different ways, if possible. A high reliable study is also similar to the deductive approach, explained above, in the aspect of enable a possibility for another researcher to perform the same study and eventually end up with the same or similar results (Befring, 1994).

The reliability of this study has different levels depending on what areas that are illuminated. Starting with the theoretical parts, the information is gathered from different sources such as books and scientific articles. These sources are as described above mostly considered to be secondary information, reducing the reliability. Although secondary information, the sources comes from authors that are well known in their field and the scientific articles are all peer reviewed ensuring high quality and reliability. Furthermore, for the majority of the theoretical information multiple sources has been used to compare and strengthen the theory, increasing the reliability further as Saunders et al. (2009) writes.

The reliability regarding observations has been discussed above where the collected information has been checked to minimize misunderstandings. The same procedure has also been used regarding the interviews. Furthermore, multiple sources have been used when possible, gathered from both the observations and interviews. However, multiple sources have not been possible in every occasion, since experts with specific knowledge have been used in some cases. To ensure high reliability when this occurred, the experts have been asked to explain the specific case once again at a later point. Regarding the information collected from the software system, everything has been controlled with the most knowledgeable personnel that have been used in the study. This routine has made sure the information is accurate and up to date.

2.9.3 Objectivity

Objectivity of a research reflects the extent of how the study has been affected by different considerations and subjectivity (Denscombe, 2009). One example is if the bias of an interviewee has been accounted for and considered. This is especially relates to the data collected through interviews and observations according to Doody & Noonan (2013).

The interviews and observations in this study have been performed with this consideration. Since the study has collected the majority of the empirical findings from the personnel working at Willo, are aspects of objectivity very relevant to discuss. During observations and interviews, different employees are bias depending on their position and function in the organization (Denscombe, 2009). Considerations have therefore been done during the analysis of the results. Furthermore, it is also important to lift the positive aspects to assess alternative solutions through different perceptions. The subjective information will therefore be assessed together, and by that form an object solution helping to improve the processes without forgetting important reflections.
2.9.4 Generalizability

Generalizability represents the ability to estimate assumptions regarding other similar studies from the results generated by two or more studies (Denscombe, 2009). This can only be done if the study is performed in a standardized or common way. The generalizability aspect is important to consider, since the research could be used in some occasions in other cases, making the study applicable to more areas than the researcher first intended (Denscombe, 2009).

This study has previously been classified to have a case study strategy, which can be argued to be hard to generalize. The reason to this is that it is based on a single case at Willo and can therefore not be applicable for another company (Denscombe, 2009). In general, to be able to generalize a case study there are some aspects that are necessary to consider. These aspects include finding important characteristics in the study that could reflect other similar cases, and enable the ability to compare these characteristics among studies (Denscombe, 2009). Since planning the production is considered one of the basic functions of a manufacturing company as Olhager (2011) describes, could small parts of this study also be applicable to similar growing companies. These companies could have a similar production layout or similar type of products. Furthermore, companies that have a large portfolio of products can have use for the classification model developed in this study. The model takes advantage of two theories of grouping products together, and by doing so identifies products with similar manufactural specifications. The results are therefore considered generalized in a sufficient way of a study. Especially the classification model could be considered generalizable, and therefore the development has been described in detail to facilitate the use to other companies in similar situations.
3. Theoretical framework

In this chapter, the theoretical framework of the study will be presented. Starting with larger organizational theories to form a broad framework later used when comparing Willo to the theory in the analysis. Further, describe planning and production expressions, customer relations, and introduce more detailed production planning theories to which Willo’s process will be compared with. This so future recommendation later can be presented in the analysis chapter according to research objectives.

3.1 Supply chain

According to Hill (2005), companies rarely have all resources to produce a product from start to finish. The steps a product will take during production and delivery is known as a supply chain (Jonsson & Mattsson, 2011). In a supply chain, companies perform different tasks. Some companies focus on raw material such as extracting and producing metal, others focus on manufacturing the specific product, while others focus on distribution of products to different markets (Hill, 2005; Agrawal, et al., 2014). The supply chain’s layout and size depends greatly on the complexity of the product or service, where the number of suppliers and retailers differ. Generally, there is one main stakeholder in a supply chain located in the centre, producing the actual product (Agrawal, et al., 2014). Upstream to this stakeholder are suppliers and downstream there are different distributors and retailers until reaching the end user, (Hill, 2005). The suppliers and retailers are divided into tiers, depending on how close to the big stakeholder they are. For example, a supplier extracting and producing metal could be a tier 3 supplier for a car manufacturer, meanwhile a tier 1 supplier for a company producing wire. The numbers start from the lead stakeholder and rises up- or downstream as far the suppliers and retailers stretches. In the Figure 9 below a supply chain can be seen illustrating the complexity and tiers (Agrawal, et al., 2014; Garcia & You, 2015).

![Figure 9: Supply chain Illustration (Hill, 2005; Agrawal, et al., 2014)](image-url)
3.2 Focus operations

Businesses can choose to focus their operation around some different approaches to gain a competitive advantage (Laosirihongthong, et al., 2010). Hill & Hill (2009) describe alternatives where a company can choose either to focus around their resources or markets but also a combination of the two, see Figure 10. The choice will be done via six approaches; process, volume, variety, geography, products, markets or order-winners (Hill & Hill, 2009).

![Focus around resources vs Focus around markets](image)

**Figure 10: Alternative focus choices (Hill & Hill, 2009)**

- **Process.** Products that utilize similar processes are grouped together, gaining units with a process focus. The aim of this focus choice is to gain benefits in form of centralized knowledge and a higher process utilization (Hill & Hill, 2009).
- **Volume.** In this focus choice the products are divided depending on the production volumes. This will facilitate the dimensioning of the production’s infrastructure where decisions will depend on the volumes a specific process supplies (Hill & Hill, 2009).
- **Variety.** Relates to the choice of dividing the production in regard to the variation of products. Where some resources process quite standardized products with low variability, while others focus on higher flexibility with a larger variety. This approach has similar advantages to the volume choice (Hill & Hill, 2009).
- **Geography.** This approach divides the operation in regard to the geographical market it supplies. This approach tends to tilt towards a focus around markets instead of resources. This is preferable when markets is characteristically different by its geographic location, usually according to Hill & Hill (2009), the products is also highly specific where the customer is involved in the supply chain.
- **Product/ market.** Operations focus on having units that serve a specific type of product or customer. This will create a focus around the specific products or customers rather than the process itself. As Hill & Hill (2009) describes can this approach be favourable when a company wants to increase the knowledge level of a specific product or market.
• **Order-winners and qualifiers.** This operational approach divides the production regarding different order-winners and qualifiers depending on their different demands. This approach will therefore be most tilted towards markets, where similar products that supplies different markets can be produced with different focus due to different order-winners and qualifiers (Hill & Hill, 2009).

These focus approaches can be according to Hill & Hill (2009) hard to fully understand and implement, therefore should considerations be done in regard to the implications of management, operations and strategic tasks. Since the analysis, of what approach to choose can be complicated is there a possibility to combine several of the above approaches. When doing so, positive aspects generated from these approaches can be gained. One approach applied on one part of the organization while another can be applied to focus a particular part in alternative direction, and by that gain a competitive advantage (Hill & Hill, 2009; Laosirihongthong, et al., 2010). Furthermore, as Hallgren & Olhager (2006) writes, the focus can be choosen depending on where the customer order decoupling point is located. The customer order decoupling point is where the customer enters the process, where the product become customized or branded with an order (see Chapter 3.4.4 for a more detailed description). The focus can thereby be chosen in one direction before and another direction after the customer order decoupling point (Hallgren & Olhager, 2006).

It is also important to understand that not all operational divisions need to be focused according to these approaches, since all approaches has advantages as well as disadvantages could it therefore be preferable to apply economies of scale (Hill & Hill, 2009). This implies that instead of focus the operation it can be preferable to build a large production that stretches over multiple countries and with that gain an advantage (Garcia & You, 2015).

### 3.3 Layout

There are a variety of ways an industry can organize and build up their manufacturing processes, which type of layout that is chosen depend on what is produced. Since a production layout change can become an expensive investment due to alternative costs has Miltenburg (2007) developed a model to help identify in what direction a company should strive depending on volume and material flow. His model can be seen in Figure 11 below and show five plus two different production layout alternatives.
In this study, the layout that is going to be further explained is the Process layout or job shop, which it is also called. The aspects that characterize a job shop are as Miltenburg’s (2007) Figure 11 that illustrates the Layout and material flow together with the product and volumes. Here the job shop is characterized by producing very many products with low volumes, and having a flow that is extremely varied.

According to Segerstedt (2008), a job shop is constructed with similar equipment are grouped together, this means all lathes are grouped in one department while the mills are grouped in another. The products are later transported between the departments and processed by the different machines (Segerstedt, 2008).

There are according to Segerstedt (2008) and Huang et al. (2008), some positive sides of having the production organized in this way:

- The manufacturing process is flexible for different circumstances
- High utilization of the machines and personnel is possible
- Low sensitivity for machine failure

Further, the authors present some negative sides of a job shop:

- High capital tie up costs, with high work in progress
- Long throughput time
- Hard to plan and administrate the production flow
- Long transportations

Furthermore, usually the entire batch is completed before transported through to the next operation and to smooth out variation, a queue is constructed. The planning of the production is hard since the flow is hard to overlook, and capacity of one operation can be available when planning a component but it is hard to estimate the capacity and availability on an operation a few weeks from present day. Therefore as Segerstedt (2008) writes, production orders has to be planned with margins, especially if a product consist of many components all produced in a job shop with uncertain lead-times.

3.4 Description of planning and production expressions

In this section, common phrases and expressions will be described. The chosen expressions incorporate some of the many terminologies that can be used when planning a production. These have been chosen due to the connection to the study and report.

3.4.1 Lead-time

Lead-time can explain different things depending on the situation. However, according to Olhager (2011) the lead-time definition is the accumulated times from which a demand of an activity or several activities is acknowledged until the activity, or activates are accomplished (Marlin, 1986). Usually the different explanations is done in three ways, the lead-time to develop a new product, lead-time until a delivery reaches the customer (also known as delivery time) and lead-times in the production process (Segerstedt, 2008; Olhager, 2011).

3.4.2 Throughput time

Represent the time it takes from the raw material is delivered to the production process until the product is finished (Mourtzis, et al., 2014).

3.4.3 Production to customer order or to warehouse order

There is a deferens when a manufacturing company produce products directly towards customer orders compared to a warehouse (Segerstedt, 2008). Companies that have a warehouse of finished products where delivery to customers take place, produces products to warehouse orders. This choice facilitate a fast delivery time to the customers. Meanwhile companies that produce highly customized products that only serve a particular customer, for example a shipyard, produces products to customer orders. Where the production starts after an order has been received. This choice of production facilitates the customizable possibilities for the customer, but therefore the delivery time is significantly longer (Segerstedt, 2008).

3.4.4 Customer order decupling point

A common struggle to the sales department is depending if a customer is willing to wait for the production of a product or not. The point of where the order of a customer penetrates the production will therefore differ, (Segerstedt, 2008; Olhager, 2011). This point is called customer order decupling point or order penetration point, and illustrates where a product
becomes branded for a specific customer (Hallgren & Olhager, 2006). The point will also depend on how fast the production is and where the point is located will determine if the company can be classified as a customer order or a warehouse order company (Banerjee, et al., 2012). Furthermore the planning horizon and planning strategy will change according to where in the process the customer order will be processed (Segerstedt, 2008; Olhager, 2011).

3.4.5 Product structure
A product structure will illustrate all the components needed to assemble a finished product (Kashkoush & ElMaraghy, 2013). This structure, also called bill of material (BOM) (Segerstedt, 2008; Olhager, 2011) and seen in Figure 12, are some common structures illustrated. Structure (a) represents a straight deep structure that can for example be how steel is processed. Structure (b) is a wide and shallow structure that could represent a product assembly with bought parts. Structure (c) has a more complex structure both deep and wide, which can be linked to most known products such as a car (Segerstedt, 2008; Olhager, 2011; Kashkoush & ElMaraghy, 2013).

![Product structures](image)

*Figure 12: Product structures (Olhager 2011).*

3.4.6 Capital tide up cost
Products that are held in inventory tie up capital, this is also the case with products in the processes called work in progress (WIP) (Olhager, 2011). The cost of this capital tide up is mostly linked to the funding of the capital, but other costs are warehouse space, material handling, insurance, and obsolescence (Taylor, et al., 2004). Since the added value put into the product increase with the throughput time, the tide up capital is at its peak level in finished goods inventory (Olhager, 2011).

3.4.7 Sequencing
Sequencing stands for in which order different products should be processed in different machines. According to Olhager (2011), sequencing problems can be very complex and
hard to calculate. Therefore, computerized algorithms are commonly used to calculate a sufficient operations plan. There are some priority rules to help to set which product that should be processed at a particular time (Doh, et al., 2013).

- First come, first served (FCFS)
- Shortest operating time (SOT)
- Earliest due date first (DDate)
- Critical ratio (CR) \[ CR = \frac{(Due \ date - Current \ date)}{Number \ of \ days \ remaining} \]
- Last come, first served (LCFS)
- Random order
- Etc.

The priority rules best fit different goals of the production, therefore in Table 2 below an illustration is shown when the rules best fit the priority of the production (Doh, et al., 2013).

<table>
<thead>
<tr>
<th>Mean flow time</th>
<th>First come, first served (FCFS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimal throughput time</td>
<td>Shortest operating time (SOT)</td>
</tr>
<tr>
<td>Average tardiness</td>
<td>Earliest due date first (DDate)</td>
</tr>
<tr>
<td>Maximal tardiness</td>
<td>Critical ratio (CR)</td>
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<tr>
<td>Makespan</td>
<td>Last come, first served (LCFS)</td>
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<tr>
<td></td>
<td>Random order, etc.</td>
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</tbody>
</table>

### 3.4.8 Grouping of products

If products are similar, they can be grouped together into product families. The grouping is often called group technology (GT) and can be performed in some alternative ways, all products that are grouped will be similar in its construction, or how it is produced (Tatikonda & Wemmerlöv, 1992; Olhager 2011). Some examples of categories according to Olhager (2011) are here listed:

- Size
- Form
- Function
- Similar production
- Operations flow
- Common fixture or tool

By grouping articles into product families, it facilitates the production by making the flows easier to understand and follow. Another important aspect is strive to lower the impact of set up times, therefore similar products can be produced in the same machine without long and costly set ups (Olhager, 2011). By planning the set ups after product families a longer set up can be performed when changing product family while, within the family only short changes are necessary. This will enable smaller batches to be produced together while still keeping the economically feasible goals. One other aspect is the learning curve of operators, according to Olhager (2011), this will be shorter if similar products are being
produced together. However, systems with grouping of products can according to Olhager (2011) be costly and should therefore be set against the potential benefits generated by the result.

Tatikonda & Wemmerlöv (1992) further describe classification and coding (CC), which can use the organized product groups according to group technology and label each with a code. The groups can therefore become classified with a specific code, which facilitate the information flow and the usage of the classifications. The system can according to Tatikonda & Wemmerlöv (1992) furthermore, assist the group technology system when retrieving information from a software system, where the coding can be conducted on existing groups. Usually the classifications in the process are generated from different specifications in comparison to specifications normally used in the group technology. The group technology does therefore origin from manufactural aspects connected to the specific products. The objectives should therefore, and by that the purpose of the classifications, as Tatikonda & Wemmerlöv (1992) describe, first be determined. This will create a foundation of how the classifications are going to function. Moreover, to facilitate a system that is used continuously, Tatikonda & Wemmerlöv (1992) describe, the importance of a modular system. The system can therefore easily be adapted for new products and circumstances. With a functioning CC system, Tatikonda & Wemmerlöv (1992) describe the benefits to be both managerial and technical where the understanding and control of the operations increase and knowledge of issues within.

### 3.4.9 Economic order quantity

A common and simple model to use when calculating optimal batch sizes is the Economic Order Quantity formula (EOQ). The calculation origins from a formula calculating the total cost a product has during a specific period. The EOQ formula will enable a calculation to be done to find at which batch size the total cost is at its minimum (Anupinidi, et al. 2014). The formula uses some product specifications during the period; fixed order cost, inventory holding cost, order size, demand, and unit cost. Below are the calculations shown illustrating the formula (Anupinidi, et al. 2014; Olhager, 2011)

\[
\text{Total fixed order cost} = \text{Fixed order cost} \times \frac{\text{Yearly demand}}{\text{Order quantity}}
\]

\[
\text{Total inventory holding cost} = \text{Inventory holding cost} \times \frac{\text{Order quantity}}{2}
\]

\[
\text{Total cost} = \text{Total fixed order cost} + \text{Total inventory holding cost}
\]

Below in Figure 13, the relationships of product cost and order quantities are shown. Note the flat portion of the total costs where the EOQ lies, meaning there are some room for variation of batch sizes without major differences in total costs (Olhager, 2011; Jonsson Mattsson, 2011).
Figure 13: Relationships of costs and order quantity (Olhager 2011; Anupinidi, et al., 2014)

From Figure 13, the letters create this formula:

\[ TC = F \frac{D}{Q} + H \frac{Q}{2} \]

Where

- \( TC \) = Total cost
- \( F \) = Fixed order cost
- \( D \) = Annual demand
- \( Q \) = Order quantity
- \( H \) = Inventory holding cost

By applying calculus on the function regarding quantity, the minimum total cost can be found where the optimal batch size exists (Olhager, 2011; Jonsson Mattsson, 2011). Revealing the EOQ formula below:

\[ EOQ = \sqrt{\frac{2FD}{H}} \]

3.4.10 Production flow analysis

Production flow analysis aims to cluster products into production groups and resources into flow groups. The analysis helps to show patterns in the correlation between products and the processing machines they flow through (Olhager 2011). To perform this Olhager 2011 describes two main approaches that are described in this section. The starting point of both approaches is a table, which show what machines a product flow through. See Table 3 for an example.
Table 3: Relationships between products and machines (Olhager 2011)

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The first approach is to move the columns and the rows until connected squares are achieved, the squares then illustrates the product groups and the machine flow groups, (Olhager, 2011). When clustering many products that flow through many different machines is the second approach more applicable.

By calculating an index of how similar two products are, regarding the utilization of resources, can larger tables be analysed. The index is a number between 0 and 1 and measure the closeness of correlation between two products.

\[ RS_{ij} = 0,5 \left( \frac{N_{ij}}{N_i} + \frac{N_{ij}}{N_j} \right) \]

Where

- \( RS_{ij} \) = Resource similarity of product i and j
- \( N_{ij} \) = Number of resource types that both product i & j need
- \( N_i \) = Number of resource types that are needed for product i
- \( N_j \) = Number of resource types that are needed for product j

If two products share all resources, the index becomes 1 and if no similarity exists the index becomes 0. Product groups are later formed from the connections between two of the products, and later within each pair or group. The resource similarity is always measured from the strongest connection from two of the products within each group. With this approach, all of the products will eventually be calculated and checked for resource similarity. The result can be illustrated in diagrams or in tables showing the resource
similarity. Below in Table 4, the result are presented from the analysis, however a similar result can be achieved by moving rows and columns (Olhager 2011).

Table 4: Product and flow groups after analysis (Olhager 2011)

<table>
<thead>
<tr>
<th>Machine</th>
<th>M3</th>
<th>M6</th>
<th>M7</th>
<th>M10</th>
<th>M1</th>
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3.5 Conflicts, and trade-offs

Profitability, quality, short deliveries, resource utilization, inventories, productivity, and flexibility are all goals that businesses try to fulfil. However, these often contradict themselves, where most strive towards different priorities. Therefore decisions have to be taken where trade-offs are prioritized and weighted to find the best solutions to problems (Shahbazpour & Seidel, 2007; Segerstedt, 2008; Olhager, 2011). In Figure 14, three common priorities are illustrated. High delivery capability can be performed with a large warehouse with finished goods, however, the warehouse tie up capital. One other way, always to secure the delivery is to have resources in form of personnel and machines available and waiting for a customer order, this creates low resource utilization and in return high costs (Segerstedt, 2008). This is a trade-off where the management has to decide which categories that should be prioritized (Olhager, 2011).
These decisions can be hard to stress especially if individual performance indicators measure different departments. Therefore are risks high of sub optimization and if the organization strive towards different goals. Managers have to find a suitable solution or as optimum as possible between these categories, and furthermore strive towards minimizing the negative effects of the decisions that have been taken (Shahbazpour & Seidel, 2007; Segerstedt, 2008; Olhager, 2011).

### 3.6 Customer relations

When a customer purchase a product from a supplier, is there usually one form of agreement between the parties. Depending on the type of agreement can it be a written document or a silent handshake, but there are usually one form of established agreement prior to the sale, these agreements can according to Jonsson & Mattsson (2011), be divided in four types:

- Sales in direct competition
- Sales with agreement in competition
- Sales with operative agreements
- Sales with strategic agreements

The sales in direct competition are the most common approach, where the supplier is exposed to competition whenever the customer is purchasing products. In this type, there are no contracts or agreements between the parties, meaning that a new temporary agreement has to be established before each sale. The assessment of supplier will be according to price and delivery, therefore can these relationships be costly for the suppliers and generate long lead-times for the customers (Jonsson & Mattsson, 2011).

The second type of customer relation is sales with agreement in competition, which relates to a basic agreement between the parties are in place. The agreement concerns prices and delivery conditions, however the customer is not obligated to only purchase products from the particular supplier, hence the competition (Jonsson & Mattsson, 2011).

Third type, sales with operative agreements, is adapted for longer relationships with agreements covering more than price and delivery conditions. The agreements are renegotiated in even periods but are never left for competition and customers will
therefore seldom change suppliers (Jonsson & Mattsson, 2011). The agreements can incorporate a volume of 75% of the yearly demand for a product, whereas another supplier has the remaining part. Furthermore, as Jonsson & Mattsson (2011) describes, due to the suppliers of an agreement of this sort are less exposed to competition, will a new possibility open up to share information. This enables a smoother production and material flow by using suborders and delivery schedules can the fixed ordering cost also be decreased.

The fourth and final type is the most long-term agreement between the four, where the agreement will further include cooperation of more than just manufacturing. The cooperation could include product development, quality development, etc. Furthermore, this agreement could also include available capacity at the supplier or a constant flow of raw material. Usually these agreements will lack a predetermined date of cancelation, and therefore continue to function year after year. The supplier has the entire demand and no competition exist, except yearly price negotiations. Regarding the information exchange is it at this level used extensively and integrated in the businesses (Jonsson & Mattsson, 2011).

**Agreement specifications**

The types of relations explained above all include different agreement specifications regarding price, delivery, minimal order size, etc. (Jonsson & Mattsson, 2011). Below are some common specifications listed and explained:

- **Fixed price with incentive.** An agreed price is fixed but the supplier can receive a premium reward if certain accomplishments are surpassed, for example quality and delivery precision.
- **Cost related prices.** If the supplier has trouble to calculate prices, due to uncertainties regarding volumes, could an agreement related to the costs be set. The price would be set in relation to the actual costs of manufacture, and could include a performance bonus to create incentive to reduce the costs.
- **Price with clauses.** Include an agreed price but with a clause, which enable the customer to change supplier if a lower price is offered. Alternatively, force the existing supplier to match the new lower price.
- **Flexible delivery quantities.** For products with uncertain demand, could an agreement with a specific volume be a problem for the customer. Furthermore, could an uncertain volume be a problem for the supplier, since material has to be purchased etc. Therefore, an agreement could specify one price for one volume size, which can change with increasing/decreasing volumes. The agreement could also include rules what the customer is obligated to do if volumes change.

**3.7 Planning strategies**

In general, there are four different planning strategies to how the production of products will be handled. These determine what parts of the production that should rely on forecasts and which that should rely on actual orders (Olhager, 2011; Rafiei, et al., 2013).
• **Make to stock.** Products are planned with forecasts and are produced to a warehouse where they wait for a customer order (Olhager, 2011). Suits high volumes with batch or line flow with products of narrow range (Hill & Hill, 2009).
• **Assemble to order.** Products are planned and manufactured with forecast but maintained as modules. When a customer order is received, an assembly of a number of modules will finish the product where the delivery ships it to the customer (Olhager, 2011). This approach best suits companies that are in between make to stock and make to order (Hill & Hill, 2009).
• **Make to order.** Raw material is purchased with forecast as a decision category but the manufacturing will not start unless a customer has ordered a product (Olhager 2011; Alfieri, et al., 2012). Suits markets with low volumes and a wide range of specialized products (Hill & Hill, 2009).
• **Engineer to order.** Nothing is purchased or started unless a customer order is received, serves as the extreme segment with long lead-times but total customizable ability (Olhager 2011; Alfieri, et al., 2012).

### 3.8 Production planning

Planning the production is as Olhager (2011) describes one of the basic functions of a manufacturing company. Further described are the overall goals of production planning according to Olhager (2011), these are:

- High precision regarding delivery and short lead-times
- Low manufacturing costs and high and even resource utilization
- Low costs of tied up capital through short throughput times

These aspects are all important but usually it can be hard to optimize them together, prioritizations are therefore necessary as described in Chapter 3.5. Different priorities can be chosen depending on the effect the company is aiming for (Olhager, 2011). Shortening of lead-times can for example, create a stronger position in the market, and according to Segerstedt (2008), a higher price of a product compared to competitors be motivated if the lead-time is shorter. The main task of production planning is however to ensure that resources are available when needed where needed, the resources can be personnel, material or equipment that together are producing value (Olhager, 2011).

Production planning is further as Vollmann (2005) and Olhager (2011), describes done in different stages, illustrated in Figure 15, depending on the time horizon of the specific plan. The main strategic plan decides the overall direction of the business. Further down is the sales and operations planning that have the second longest time aspect reaching about 1-5 years. The master production scheduling representing the yearly plan, material requirements planning representing 2-6 months and lastly the production activity control has the shortest, day to week plan. These plans are all important and serve different purposes, ranging from strategies and capacity to resources and specific machines needed for a specific product (Jacobs, et al., 2011; Olhager, 2011) Usually as Kreitner (2009) describes the planning horizons overlap, therefore the boundaries are not rigid and will shift depending on the organization. For example, lower level managers are generally in charge of the monthly and weekly plans but also help to decide the yearly plans. By doing
so, the organization becomes more integrated and more likely to strive towards the same goal (Kreitner, 2009).

3.8.1 Strategic plan

The strategic plan reaches over a long period, the time aspect differs between companies, but it generally reaches to 5 years and beyond. The responsibility lies on the top management where decisions of investment priorities and performance indicators are decided (Hill 2005). The business is controlled at this level to fulfil the needs of the customers and market segments, but also to find deviations and correct downstream problems so the overarching strategy is kept as the target (Kreitner 2009). The general vision of the business is later broken down into more manageable goals in each department, this is where the sales and operations plan will take place.

3.8.2 Sales and operations plan

Sales and operations planning create a focus from the strategic general vision for the different departments. As for the production it provides a basic framework that later will be broken down into the yearly, monthly and week to daily plans (Vollmann, 2005). For sales and operations planning there are, according to Vollmann (2005), four aspects to which the managers has to reflect upon, these are; demand, supply, volume and mix. These aspects have to be balanced in a manufacturing company, and will in that case facilitate to show the big picture to middle managers. At this level, the plan is rough and uncut. However, further down in the other steps of the planning, will the plan become more detailed and manageable (Vollmann, 2005).

For the production planning aspect, does sales and operations planning incorporate the aggregated product groups and larger flow groups of machines. Since actual information in this time horizon is hard to detect, are sales and operations plan mostly controlled with forecasts generally to detect deviations in capacity and resource demand (Olhager, 2011). Furthermore the chosen planning strategy of a level, chase or mix strategy is here included in the decision. Level strategy represents a smooth production level even though the demand shifts. Chase strategy symbolize that the demand is always chased where the

*Figure 15: Planning horizons (Vollmann, 2005; Jacobs, et al. 2011; Olhager, 2011)*
capacity is adapted to the actual demands, with for example layoffs of personnel. Mix strategy is a combination of both (Jacobs, et al. 2011).

3.8.3 Master production scheduling

Master production scheduling further breaks down the sales and operations plan and make it more linked to the production where a preliminary manufacturing program will be tested (Segerstedt, 2006). This is performed by taking the current inventories and the forecast of future demand and thereafter matches suitable manufacturing volumes to cover the forecast (Segerstedt, 2008). In this case, net requirement planning or cover time planning can be used, but other methods such as order point systems are also possible.

According to Segerstedt (2008) is net requirements planning possible to conduct if:

- Production plan for end products exists and is always updated
- Structures of end products, specifying which sub products they consist of
- Inventory levels is measured and accurate
- Lead-times for all articles are known and accurate

The result will show if the calculated production hours needed to complete the batch is available. Later the results will be checked against available capacity in form of machines and personnel, and if the volume of products can be produced during the requested lead-time. These calculations can be performed either by hand or by a software system, but when performed by hand, simpler spread sheets can be used (Segerstedt, 2008).

As Duchessi et al. (1989) says it is important that the data are accurate. Since if there is a suspicion of lack of quality or accuracy in the data, it cannot be used in a sufficient way. Since the master production scheduling uses forecasts and not real orders should some precautions be used, but if a steady growth of demand can be seen investments in capacity can be done. During this horizon, investments in machines and personnel are still possible whereas further down in time horizon it is no longer possible (Segerstedt, 2008).

Furthermore, raw material has to be controlled and managed in a similar way, therefore information regarding lead-times from suppliers is here incorporated into the production planning (Segerstedt, 2008).

3.8.4 Material requirement planning

The material requirement planning will focus on specific products and specific resources, the calculated demand in the master production scheduling will be split down into separate schedules depending on end products or components (Segerstedt, 2006; Jodlbauer & Reitner, 2012). According to Segerstedt (2008), the aim of a suitable material and resource plan is to:

- Keep promised delivery times
- Follow the master production schedule
- Make sure that material, resources and equipment is available at the right time in the right place
- Keep the level of the production steady
- Minimize the costs for work in progress
With these, the material requirement plan will control the production closer in time and make sure the right products are being processed (Jodlbauer & Reitner, 2012). The material requirement plan will incorporate actual orders where possible to manufacture directly to customer orders. This will help the finished goods inventories to be kept low (Segerstedt, 2008; Olhager, 2011).

3.8.5 Production activity control

The production activity control will further down focus on exactly how a product is being processed with different activities and operations. The production plan will generally incorporate an operations plan and instructions on how the operations should be performed. This is the shortest planning horizon and stretches from an hour to a day, where most of the information is direct instructions to operators (Browne, 1988). Another important aspect in this planning horizon is the follow up where the operators report how many products they have processed, total time, time per product, setup times, etc. These will later be used as assessment of the production plan and if changes are needed in the future (Segerstedt, 2008; Olhager, 2011).

3.9 Forecasting

Every decision has been based on a forecast in some way. A forecast can be consciously or unconsciously and based upon an established technique or just a feeling (Segerstedt 2008; Thompson 2013). For example, a decision to purchase a new machine with the forecast of believing the resource demand of that particular machine will increase in the near future. Therefore are forecasts important for all kinds of manufacturing companies, as Olhager (2011) describes. Companies controlled with customer orders can function without forecasts concerning the production of products. However, Olhager (2011) argues that forecasts for these kind of companies are important to time resources adaptations of investments in machines, facilities, and personnel.

Forecasts have some basic properties according to Olhager (2011).

- **The forecast is usually wrong.** The control system should be able to handle the differences between demand and forecast and therefore also the error of the forecast.
- **A good forecast is more than a number.** The forecast should also include a measure of expected forecast error, or a standard deviation of the error.
- **Aggregated forecasts are more reliable.** Forecasts based on product families are generally more reliable than for individual products.
- **Accuracy of the forecast decline with the horizon of the forecast.** It is easier to determine the volumes for the nearest month than for a month in the distance future.
- **The forecasts should not replace known and confirmed data.** Even if good forecasts can be generated, could it be unnecessary if good information exists. The information can include real demands from big customers with long and secure delivery agreements, or known sale campaigns.
Forecasts can be performed in different ways. Here some common types of forecasts used in manufacturing are mentioned by Segerstedt (2008):

- **Experience and feeling.** When longer forecasts are performed and when it is hard to base the forecast on information or facts.
- **Multiple variable techniques.** When variables depend on other variables can regression models be used, by doing so, an explanation of the correlation to the wanted forecast objectives can be generated.
- **Single variable Techniques.** When a forecast depend only on single variable. Example of forecasting techniques are; moving average and exponential smoothing.

There are further aspects to account for when forecasting are performed, especially since a forecast will be the foundation when taking important decisions in an organization. Therefore should the consequences of the decision be correlated with how the forecast is generated (Olhager, 2011).

Olhager (2011) defines some questions that are important when performing forecasts.

- **Time horizon.** How far into the future should the forecast reach? In general should the forecast be as long as or longer than the production lead-time for a specific product.
- **Detail of the forecast.** Is it sufficient to use forecasts on product families or are forecast for each product needed? In which intervals should the forecast be revised?
- **Amount of forecasts.** Should all products have forecasts? If one product is critical for the company, could the resources be focused on this? In contrast, if a company have a high variety of products should focus instead be on a standardized process to handle the forecasting.
- **Planning or control.** Is forecasting needed? When planning the production is performed, an assumption regarding demand can be taken, this assumption can be, no deviations in demand for a coming period. Instead, other systems can be used, such as signals of deviations.
- **Stability.** If a stable demand exists, if it does, could it be used to forecast the future. Otherwise is more input needed in order to estimate a plausible forecast.
- **Current processes.** Who will perform the forecast and how detailed is it expected to be? What information exists and what additional information is needed? How much does the forecast cost and is it economically feasible to collect the additional needed information?

Olhager (2011) further explains that good forecasts can lead to shorter delivery times and a smoother resource utilization of employees and machines. These results can be applied to calculate a more economic inventory control for the manufacturing. The need for forecasting in different stages when producing a product differs, depending on where in the process the customer puts an order. Therefore should the focus of the forecast adapt accordingly. Olhager (2011) illustrates this with Figure 16 where the correlation can be seen between customer order decoupling point and the focus of the forecast.
3.10 Control and support systems

There are many ways to control and support the production, this is conducted by software programs, most commonly known as Enterprise resource planning systems (ERP) that incorporate most of a manufacturing company’s organization (Segerstedt, 2008; Powell, et al., 2013). The software is thereby linked into finance, marketing, production, sales, etc. where different modules represent each department see Figure 17. There are different developers providing software programs suitable for different types of companies and with different focus (Powell, et al., 2013). The base of most of the systems is in the centre module consisting of the basic data of all products and operations through the manufacturing process (Powell, et al., 2013). According to Segerstedt (2008), the master data module incorporates a registry of these areas:

- **Articles.** Including article numbers, drawings, lead-times, safety stock, cost, etc.
- **Bill of material.** Including the structure of components needed for an article
- **Operations.** Including all operations necessary to complete an article, with setup times, operation time per component, etc.
- **Planning groups.** Including the machines and processes where the component is manufactured, with capacity, number of shifts, number of machines, etc.
- **Equipment and tools.** Including the tools needed for a specific operation and where the tools are located
- **Shop floor calendar.** Calculates the lead-times from production hours to actual weekdays concerning shifts and holidays.

These form the foundation of data that the other modules later will use to calculate the specific information needed (Powell, et al., 2013). Segerstedt (2008) follows to explain some common modules, and how a company can benefit from them. The following parts will include some modules, which are important for this study. These modules will together facilitate a smoother administration of the production where the main focus is to shorten the lead-times for the customer by deliver with high precision, low capital tie-up cost, high
resource utilization, high product quality, and low administrative cost of controlling everything (Segerstedt, 2008).

**Figure 17: Modules in a software control and support system (Segerstedt, 2008)**

**Material control**

This module controls the inventory, with actual levels and planned future, in and out deliveries (Segerstedt, 2008). If inventory levels descend below the reorder point, a signal is sent that a refill is needed. This will calculate the on-hand inventory levels at a future date with regard to lead-times, in and out deliveries and adjustments. This will together with other functionality such as economic order quantity be used to find good solutions to handle inventories (Segerstedt, 2008).

**Master production scheduling**

This module is used when conducting the future master production scheduling that has been explained in Chapter 3.8.3. Here the articles grouped in families are planned in regard to demand and inventory levels. The planes generated are later tested to see if there is free capacity to manufacture, after modifications the plan will be called, rough-cut analysis and is the plan that will be used in the next planning horizon (Segerstedt, 2008).

**Material requirements planning**

This hierarchy level will go further down and decide the more detailed plan for the manufacturing and purchase. Here the rough-cut analysis will be broken down into specific articles, where all components will have a detailed plan incorporating forecasts and inventory levels. The components are specified with actual manufacturing quantities and are controlled against available capacity for conformance. Furthermore, this module together with the above creates a complete production planning system (Segerstedt, 2008).
Shop floor control

This module will, from the material requirements plan generate a detailed scheme of the different operations that a component will go through. This plan incorporates the documentation needed in every operation and a system how operators can report time and amount processed. This represents the day-to-day work in a manufacturing company, and specifies the efficiency and availability of machines and personnel (Segerstedt, 2008).

Purchasing

A module that incorporates all components and raw material needed to be purchased to the manufacturing. In purchasing, the order quantities and lead-times are important factors to follow, therefore suggestions are generated from the software optimizing different aspects depending on product or supplier (Segerstedt, 2008). Support from the purchasing module can also incorporate historical orders, suppliers, quotations, etc.

Order management

This module handles all the information of the customers where the information will facilitate to price a product to different customers. Other information include delivery documents, credit limit, currency, order confirmation, etc. (Segerstedt, 2008).
4. Identification of current situation

In this chapter, Willo will be presented together with their organization, products, production, and ERP-system. Further, the production planning process is presented in detail with a developed process map to clarify decision points and potential obstacles. The chapter will present the information according to research objective 1, and open the possibility to answer the other research objectives.

4.1 Willo AB

Willo AB is a family owned manufacturing company with an organizational chart that can be seen in Figure 18 (Willo internal documents, 2014). The Figure illustrates how the CEO and owner is on top and with the board of directors together having the overall responsibility of the business. Quality and environment is lifted as the most important department of the organization since there is one of the main reasons why customers choose to work together with Willo and therefore a high requirement (Willo internal documents, 2014). Furthermore, the divisions, Sales, Production, and Administration consist of managers and personnel in their particular fields. Inspection and Manufacturing consist of work leaders responsible for the subgroups and personnel working under each department. Production support has no work leader but the personnel answers currently to the production manager directly. Overall, there are around 85 employees working at Willo AB (Willo internal documents, 2014).

![Willo AB organizational chart](image)

To understand Willo further and their organization the business concept is here presented:

*Willo shall be the market-leading supplier of small, complex critical parts* (Willo, 2015f).
To succeed with the business concept, Willo need to please their customers in a better way than their competitors do, over a long period. This will, according to Willo (2015g) be achieved by following their philosophy consisting of points that will encourage the personnel and capitalize on the commitment, expertise and values, called “Willosophy” (Willo, 2015g).

- Quality is the watchword in everything I do. Good order is confirmation of my quality thinking.
- The customers can rely on me.
- Clarity and transparency characterise my communication and my way of working.
- We are all responsible for maximising every machine hour.
- I am fully responsible for my job at the same time I maintain a firm view of the totality.
- I see the value of and can pursue change processes.
- We care about each other, we help each other and we share our knowledge (Willo, 2015g)

Willo is according to their business concept, a manufacturer of small complex critical products, which can be translated into demanding products with the need for high precision. Mostly lathes and mills perform the process of manufacture, but other metal processing machines are also used. Willo specialize in producing these types of products with a higher quality and at a lower price than what their customers can do by themselves. With this focus, Willo do not develop their own products and thereby do they only produce products their customers own. Since the business focus has only been on manufacture, they have become one of the market leaders of helping their customers produce products matching this description. Willo has a wide range of customers, consisting of end users, lead stakeholders, retailers and subcontractors, which make Willo to a tier 1 to 2 supplier. When Willo produce to the end user, the customer will in that case be, another manufacturer using the product in a machine to produce other products with the help of the products purchased from Willo (Backgård, 2015).

Willo now serve around 60 customers with products in different segments. The segments explained in Chapter 1.1.2, consists of; Willo Medtech, Willo Energy, and Willo Precision, each name represent the general field in which the end use of the product will serve. The segments in which Willo operates are largely affected by laws and regulations from governments and states. Therefore, necessary market requirements have to be fulfilled, which differ depending on the selected segment. For example, the documentation and traceability of the processes of producing differ between the segments. Since Willo need to adapt and please their customers independently in which market segment they operate in is this an important aspect for Willo to account for. The necessary competence and procedures needed to fulfil the requirements work as an entry barrier to new competitors in the particular fields. Independently of market segment, the importance of reliable delivery and product quality imbues the entire organization at Willo (Backgård, 2015).
Willo now face a transformation within the business, the turnover has grown around 10% per year during the last few years. The market segments have all grown but the largest contribution has been to the Precision segment with new customers and new possibilities. The transformation starting a few years ago will eventually take Willo on a journey of doubling their turnover, to be able to supply the new customers they have invested in new machines, facilities, and personnel. With new space, Willo has the prerequisites to fulfil their business concept and management goal of doubling the turnover (Backgård, 2015).

4.2 Products

Willo has no own products, as described in Chapter 4.1, the business is thereby dependent on the customers supplying them with drawings and specifications explaining how the products should be produced. After production, the finished products are usually assembled or incorporated into another product by the customer, meaning Willo is a tier 1 to 2 supplier.

As explained, Willo specialize in producing small demanding products with the need for high precision (Willo, 2015b). In the last two years, Willo has produced around 1000 different products fitting this description. The volumes are ranging from a few pieces per year to over eight million pieces per year (Willo internal documents, 2014). The products also differ in size, from around one centimetre in length and two millimetres in diameter to products with the dimensions of around ten by ten centimetres. All products are still considered small, even if large variations between the smallest and largest products exist. The decision of product size has dimensioned the machines to process products like this.

The market segments of; Willo Medtech, Willo Energy, and Willo Precision have some typical products in each segment, these are:

- **Tyre tech valves in Willo Precision.** Used when moulding tyre patterns in car- and truck tyres, the small valve let air escape but keep the rubber from the tyre inside the mould. These products are very small and have an external diameter from two mm and up.
- **Dental prosthesis screws in Willo Medtech.** Used when fixing a new tooth in the jawbone of a patient.
- **Top- and bottom plates in Willo Energy.** Used in nuclear reactors to hold the nuclear fuel in place during operation.

The products are produced in different activities, called operations. The number of operations to complete a product differs, but around 80% of the products have between 1 and 8 operations until a complete product is created, see Figure 19. All these operations are either performed or monitored by personnel. The operations also include activities performed outside of Willo. These bought operations can be heat treatment, surface coating, and assembly for some of the products. Furthermore, Figure 19 illustrates all products in Willo’s portfolio, not only the 1000 products produced over the last two years (Backgård, 2015). This means the sum of products in the figure is close to 2000 and includes products that Willo have not produced in a few years. With an illustration, showing all products will the impact of trends and changing of products be minimized. Instead, the
general number of operations to produce products at Willo is given. Therefore, it can be used as a representation of operations during a longer period.

\[ \text{Number of operations per product} \]

![Number of operations per product](image)

*Figure 19: Number of operations to complete a product*

### 4.3 Manufacturing

Willo manufacture in Växjö and the facility consists of five linked buildings where one is newly built. One of the buildings consists of office and cafeteria where the others are designed for manufacturing. The layout of the production is a functional workshop where the buildings are divided into “flow groups”. The flow groups represent similar machines or one type of machine, which are grouped together. The machines are later individually divided into “production groups” to facilitate the planning of the production for each machine. For example, a flow group can consist of five lathes, while each lathe individually represents a production group (Sigvardsson, 2015).

Manufacturing processes consisting of manual labour are also grouped into one main flow group, and later divided into production groups depending on the task performed. In total, the manual and machine processes summarizes to 16 flow groups and 150 production groups.

The decision of grouping similar machines together and label each machine with a production group has been chosen by Willo mostly due to two reasons. First, the specific knowledge needed to run the machines, secondly because of making a constantly changing and complex production flow more manageable (Sigvardsson, 2015).

The production flow of one type of product can easily change, since there are large amounts of different products. Additionally there are also big variation between the
products all produced by similar machines. This means, a product produced in one machine one time can be produced in another similar machine a month later. All depending on which machine that has available capacity and capabilities to produce the specific product at a specific time. However, Willo strive to adapt a first come, first served sequencing philosophy. Furthermore, the reason to change the flow of a product is due to large variations of products and volumes. Willo strive to utilize the machines as much as possible and this is accomplished by using highly flexible machines, capable of processing a large range of different products. These decisions are reasons why the flow is very complex and hard to map (Sigvardsson, 2015).

The personnel working at Willo are divided by the different flow groups and usually do not cross over to other flow groups. Depending on the specific demand in each flow group the personnel will work daytime or in shifts. Willo now have daytime personnel in some flow groups, but the majority of flow groups have two or three shifts. Even though the personnel do not generally change between flow groups, many employees have the knowledge to do so. Therefore, the possibility exists, to change the capacity of personnel, if demand drops in one department and increase in another (Sigvardsson, 2015).

4.4 Enterprise resource planning system

The control and support system or ERP-system used at Willo is called Jeeves and is constructed by different modules, each containing information about a specific topic. Regarding production planning, some modules are commonly used, these are; master data, material control, material requirements planning, shop floor control, and purchasing. Each module works together with the others and create a strong base of information (Willo internal documents, 2014).

- **Master data.** It is here the information of all products regarding setup times, cycle times, operations, etc. are gathered. In addition, information regarding customers is stored here.

- **Material control.** This module shows actual inventory levels as well as when planned material deliveries will occur. Furthermore, the planned out deliveries are also shown here, making it possible to see planned inventories at a specific date in the future.

- **Material requirements planning.** This is where the detailed production plan takes place at Willo. Yearly or monthly forecasts are inserted for A and B articles and manufacturing orders are here released to the manufacturing. The manufacturing quantities are set concerning EOQ, customer forecasts/orders, and available capacity, where the prioritization among the three depends on which product and customer it is.

- **Shop floor control.** This module will take the manufacturing order and label it with the specific documents necessary for the operators to perform the operations. Furthermore this module facilitate reporting of processing time and amount processed.
- **Purchasing.** At Willo this module, incorporate the raw material that is purchased as well as tools for the manufacturing. In this module, suppliers and prices are collected, together with minimum order quantities and EOQ for the materials.

A focus of producing as good and as fast as possible, leaving little room for improvement and updating work has generated an effect that the software system supporting production planning decisions has become outdated and no longer give the support that it was intended to do. For example, the master data have therefore not been updated with cycle and setup times when changes to products have been performed (Sigvardsson, 2015).

Today the production planner is therefore forced to change dates and follow up operations and quantities in a larger scale than intended. Operators have also not prioritized to report processing times and amount after each operation and therefore it is hard to track where products are located at a specific period in time (Sigvardsson, 2015).

### 4.5 Customer agreements

Willo has, as described, around 60 customers, which together have accumulated around 1000 different products over the last two years (Willo internal documents, 2014). Around 80% of the 1000 products are produced to 20% of the 60 customers (Sigvardsson, 2015). This approximation generate that 12 customers have around 70 products each, which sums up to 12 customer stands for 840 products. The rest of the customers have around 3 products per customer, with a sum of 144 products (Backgård, 2015).

Most of the customers have a form of customer agreement, the once that do not, are customers that seldom order products from Willo and/or with lower quantities. The customer agreements can be written by Willo themselves or, which is the most common, by the customer. Since the customer writes most agreements, they are very different from each other with regard to specification and clarity of agreed terms. The agreements commonly include product prices, product specifications, and specifications regarding delivery among others (Backgård, 2015). Product specifications are not considered in this study and are therefore not incorporated at this stage. For an example of incorporated specifications, see Table 5.

Table 5: Agreement specification

<table>
<thead>
<tr>
<th>Agreement subject</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Price</strong></td>
<td>Price per product</td>
</tr>
<tr>
<td><strong>Delivery</strong></td>
<td>Lot size</td>
</tr>
<tr>
<td></td>
<td>Lead-time</td>
</tr>
<tr>
<td></td>
<td>Forecast</td>
</tr>
<tr>
<td></td>
<td>Rounding value</td>
</tr>
<tr>
<td></td>
<td>Replacement if changes occur</td>
</tr>
</tbody>
</table>

The agreements are made per product and not per customer. Therefore, there are almost as many specific agreements as there are products, additionally there are some customers without agreements. The amount of agreements further complicates the operations at
Willo, since every product has a different agreement to include in the planning and manufacturing of a specific machine. Fortunately, bigger customers with many products usually handle most of their products in a similar way, with some exceptions. The agreements usually consist of a main agreement covering all products form a customer, with an appendix where concerned products are listed together with the specific requirements. The two parts together, main agreement and appendix with specific requirements will form a complete agreement for a specific product. The exceptions of a main agreement and specific requirements usually concerns products with low or high volumes compared to the rest of the products from the same customer, these products have a separate agreement. The requirements will form how Willo handle and plan each product. All customer agreements are closely read and monitored to make sure both parties live up to the agreed requirements (Backgård, 2015).

Areas of the agreements concerned in this study are divided into two subjects; price and delivery as seen in Table 5. The price includes the end price to the customer per product. The delivery agreement incorporates five aspects:

- **Lot size.** Indicates if there are restraints regarding even volumes, for example the packaging material can hinder a shipment smaller than 50 products. Therefore, the lot size has to be multiplications of 50, meaning, 50-100-150 etc.
- **Lead-time.** Represent if a lead-time promise has been done, regarding when Willo makes sure the customer receives the products.
- **Forecast.** Indicates if the customer is obligated to leave forecasts on the specific product. Also included could the horizons be, of monthly, quarterly, yearly forecasts.
- **Rounding value.** This value works as a multiplier with a set number of a minimum order quantity. The multiplier makes the customer only possible to order for example; 50, 100, 150, 200, etc. pieces.
- **Replacement.** This aspect indicates if the customer is obligated to purchase the products during a specific period even if changes in the product specifications are done. The replacement can incorporate raw material, work in progress and finished products.

The important aspect of replacement will control how Willo can keep inventories and how the production planning will be performed. For example, a replacement agreement can include a 6 months’ worth of demand in raw material, an 8 weeks’ worth of demand in work in progress and a 2 weeks’ worth of demand in finished goods inventories. This obligates the customer to purchase the finished goods inventory before smaller changes will take place. If larger changes are performed, the customer is therefore also obligated to purchase the work in progress, and so on. This gives Willo around the same time to produce the new products with the new set of specifications, meanwhile keeping a short possible lead-time for the customer (Backgård, 2015; Sigvardsson, 2015).

### 4.6 New products

When a customer that potentially wants to produce a new product contacts Willo, there are two main processes to go through. The first process will decide if Willo get to produce
the product or not, which is by determining the selling price to the customer. While the other process will go through the preparation needed to produce the product at Willo and in the specific machines. Both of these processes are performed in a standardized way described below (Willo internal documents, 2014).

4.6.1 Step 1

The first step of the process when offering a price to customers will determine if Willo are going to take the time to calculate or just decline right away. During this decision there are several aspects to include, first of which incorporates the size of the potential product. This is an important aspect due to the machines at Willo, where they are designed to process small products, around 10x10 cm in size (Hultqvist, 2015).

Next decisions will split the process in two, one where an offer is made to a new customer, and the other where the offer is made to an existing customer but with a new product.

When handling an offer from a new customer without a previous relation, the process will focus on the customer’s business initially. During this phase, the potentiality of the product and business will be assessed, including turnover of the business and yearly forecast of the specific product. Willo strive to build a long relation with all their customers to create a profitable relationship for both parties. Because of this, they are not interested in products only produced once and therefore companies could be turned down at this point (Backgård, 2015).

After this first screening has been performed, the process will take the same form as customers previously known to Willo. Discussions will further focus on the yearly forecast and if the product could be strategically beneficial to produce. If the yearly forecast satisfies Willo’s requirements or if another strategic benefit can be linked to the product, the marketing department will continue with the offer (Hultqvist, 2015).

This is where the calculations start, consisting of material costs, labour cost, machine cost etc. The costs for manufacture include batch size and how many changeovers that has to be done to fulfil the yearly forecast, mainly represented by the first machine. This will help to find the “economic order quantity” (EOQ). However, Willo’s “EOQ” is not calculated according to:

\[ EOQ = \sqrt{\frac{2FD}{H}} \]

Instead, their “economic order quantity” is based upon assumptions from the yearly forecast, process time in the machine and estimated time it takes to setup the machine. The process time of a batch, is aimed be kept around 1 to 2 weeks to not occupy the machine during a longer period. With these aspects, an EOQ is generated. When this has been done, the price per piece will be calculated and an offer is sent to the customer to accept or deny (Hultqvist, 2015).
4.6.2 Step 2

The next step incorporates the process of making a new product ready for production, regarded as the production preparation, this process illustrated in Figure 20. The process starts when an order is received by the sales and marketing department, where the marketing assistant uses a standardized routine to check if there is a new, or reoccurring product, the same routine as explained in 4.7.1. If the product is reoccurring, the process will continue with the routine to check the product specifications for later deliver the order to the production planner also as explained in 4.7.1. When the marketing assistant determine the order to be a new product she deliverers the order according to the routine to the marketing manager that is the first step in Figure 20, (Willo internal documents, 2014).

At this process the products already has been offered with prices as described in 4.8.1. Instead this part incorporate meetings discussing; product specifications, necessary documentation and traceability of the specific product. There are often several projects running simultaneously, therefore the project leaders keep a list of all current projects where tollgates are continuoously checked (Hultqvist, 2015).

The preparation process actually starts after the marketing manager receives the order. The first activity is when he appoints a project leader most suitable for the particular product/customer. The project leader later calls for a meeting incorporating the production, quality, and preparation, where a cross-functional project team is created. During the meetings, important aspects of what the finished product will be used for are explained. This will, together with specific areas of concern create an understanding of what the customer requests. This aims to inform if there are any specifications more important than others, which has to be performed in a different way not clearly described in the drawings. These meetings are called PQP-meetings, which stand for Production, Quality, and Preparation. Furthermore, after a general understanding of the product is gained, decisions regarding what operations and in what machines the specific product should be produced in are taken (Hultqvist, 2015).

If the customers require or if the project manager considers a risk analysis necessary, it is performed at this time with the use of a FMEA (failure mode and effect analysis). In this phase, the specifications are put into the control and support system, with necessary information regarding the different operations (Hultqvist, 2015).

In the next phase, tools and equipment needed to produce are checked for availability in-house, and if something is not available, it is ordered from suppliers at this stage. Since quality usually is a concern for many customers, the quality control systems are here established, with measurement equipment and instructions. Furthermore, the raw materials are also purchased here from the supplier (Sigvardsson, 2015).

When this have been checked and approved by the project leader a confirmation is sent to concerned personnel and the project can continue. If the project is not approved or if new information has arisen, the project team meetings will go back and revise the concerned parts once again (Hultqvist, 2015).
Next phase is when the production planner puts the manufacturing order into the production plan, at this point a confirmation is sent to the customer with a preliminary finish date calculated after the initial factors of setup times and cycle times with an added safety lead-time for Willo. This is added since the calculated times are never accurate the first time a new product will be produced (Sigvardsson, 2015).

When the time has come to start producing, a production technician will set the machine for the first time. After which a realise-meeting will take place making sure the first products produced are up to the demands of the customer. If everything is ok, the order will be realised, if not, the production technician will change the machine settings until a desired result is accomplished. After the first run, three measurements are performed; process capability, measurement analysis, and initial sample measurement. Each making sure that the processes and products meet the demands and requirements from the customer (Sigvardsson, 2015).

The last activity is when the project leader updates the project status and the project is closed. In this process there is no follow up activity, during which, the initial calculations are assessed concerning how long the setup was and how the theoretical cycle time was accurate or not (Hultqvist, 2015).
Figure 20: Preparation process, from customer order to product ready for production (Willo internal documents, 2014)
4.7 Planning at Willo

Planning at Willo is done in five levels with different horizons and focus. The strategic plan incorporates the board of directors and CEO, sales and operations planning is where the top management team discuss long-term decisions. Master production scheduling is performed with regard to capacity and resource utilization while the material resource planning consisting of the detailed production planning with manufacturing orders, production activity control represent the daily monitoring of the production. Each horizon is explained in more detail below.

4.7.1 Strategic plan

The strategic plan is part of the responsibilities of CEO and owner of Willo, together with the board of directors. The process includes the decisions where the company wants to be in the future and a plan to get there. Also included in this long planning horizon is larger investments previously discussed by the managers in the sales and operations planning. Meetings with the board of directors is performed once every second month, during these meetings the CEO of Willo informs of recent changes that could be of interest to the board. Overarching discussions and decisions are performed where it is the CEO’s responsibility to make sure the decisions becomes reality (Grahn, 2015).

4.7.2 Sales and operations planning

The sales and operations planning is a part of the top management discussions, where meetings occur once every week to discuss important events during the previous and coming week. The CEO informs the managers of decisions taken by the board of directors and changes in the strategic plan. During these meetings, discussions regarding the overall aim and direction of the business are done. This incorporates investments of machines and recruitment of personnel. Performance indicators are checked in each department and projects and investments are followed up. The time horizon covers a few years, and the decisions taken will be the base on what aspects to focus the business. Moreover, the marketing department will present the latest information from the different market segments, changes of forecasts and if new customers are in scope (Grahn, 2015).

Furthermore there is a management review once a year which oversees the entire organization concerning environmental and health regulations. These meetings are controlled by the certification organization, which has to be followed to fulfil the requirements of certain ISO and EN certifications (Willo internal documents, 2014).

4.7.3 Master production scheduling

The master production scheduling is performed in main planning meetings consisting of the marketing manager, production manager and the production planner. These meetings focus on planning the production in comparison to the strategic plan and sales and operations planning. The meetings are not specifically documented and occur around once every second month or when needed. During the meetings, the marketing manager presents the latest information form the customers with changes in the yearly forecasts and if new customers are in scope. With this information as base, they discuss available capacity of both machines and personnel. This is done to estimate if changes have to be
done to correlate the capacity with the demand. Typically, some calculations will be done to see the processing times for some main products and if it is possible to produce as much as the customer requests. Furthermore, the meetings will determine if changes have to be made and what changes, in general. Questions regarding number of shifts and how many hours a week the different stations have to be up and running will therefore be discussed. After these meetings, the three persons will take the decisions and continue the research in their particular responsibilities (Backgård, 2015; Sigvardsson, 2015).

4.7.4 Material requirement planning

At Willo the production planning itself is performed by one employee, the production planner, with the help of using the administrative software, ERP-system explained in Chapter 4.4. The main aim of the production planning is to keep the resource utilization of machines high. With the utilization as base Willo also strives to be customer order oriented, and is with around 20% of the annual turnover generated by customer order oriented manufacturing. The other 80% of the annual turnover is generated with products from customers based on different kinds of forecasts (Sigvardsson, 2015). Of these products, the majority have a forecast class, ranging from A – D. The forecast class specifies how often forecasts are received and revised (Willo internal documents, 2014).

A. Articles with monthly updated forecasts that stretches over a 12-month period.
B. Articles with one annual forecast.
C. Articles where no forecasts is received. Here forecasts are generated from the last 12-month sales.
D. Articles that could disappear within the next 12-month period.

This information can facilitate a smoother production, since the customer is often not willing to wait the lead-time it takes for Willo to produce the finished product as with the customer order products. One single planning strategy is thereby impossible to use for all their products. The production planning is thus performed differently, depending on which type of product it is (agreement specifications) and in which flow/production group it is produced. Therefore, it is not possible to implement one general production plan at this point. By dividing the production plan into two parts, the production planning will be easier to understand and describe. The parts are divided into one that is customer order oriented, and one that is forecast oriented (Sigvardsson, 2015).

**Customer order oriented products**

A part of Willo’s customers does not have strict specific requirements regarding lead-times. These customers will order a set of products and receives a preliminary delivery date, explained in Chapter 4.7. This means the customer order decoupling point is located at the same time as the customer order. To have a sense of yearly volumes these products are labelled as forecast class C. Products planned with a customer order orientation means that as soon a customer order is received, an order is released to manufacturing and the production will start to produce when available. Before this can be done, the production planner will make sure that raw material is available. If there is a lack of raw material, an order has to be put to the supplier and the lead-time added to the calculation, further explained in Chapter 4.7. Since lead-times for raw material could be as long as 6,5 months,
the result of an actual lead-time will vary a lot depending on if raw material is in stock or not. When raw material is available, the production planner will to check if capacity exists and available in the resources needed to produce the specific products at that time. This capacity incorporates the machines and personnel needed to produce the products. When this is done, a preliminary delivery date will be sent to the customer, the production planner will put the order into the system, and the manufacturing begins. For customer order oriented products, the products will only be produced when and in the amount that is ordered by the customer. In some rare occasions, a larger batch will be produced at Willo, but this is almost only in collaboration with the customer and if special needs exist. This approach of start plan the production after an order is received is possible since the specific requirements of the products is generally very high, regarding complexity, customization, precision, traceability and material quality. Because of this, the customers are expecting the production to take some time, and therefore the longer lead-times are accepted for these customers (Hultqvist, 2015; Sigvardsson, 2015).

**Forecast oriented products**

Another, bigger part of Willo’s customers has lead-time requirements according to customer agreements. These customers are usually larger and send out forecasts on most products, facilitating the production planning at their suppliers. For these products, different forecast periods are received, ranging from monthly, quarterly, or yearly forecasts. All these products have received a forecast class of either A or B as explained. Production levels are planned after these forecasts, and when changes occur, the production levels are changed accordingly. This keeps the volumes as close to the real orders as possible (Backgård, 2015).

With forecast oriented products, the production usually uses the forecast amount on the first machine where a specific batch size is produced. The batch sizes depend on; order lot size, EOQ, yearly forecast and changeover time. After the first machine the products will either, continue and produce until finished, or be left as WIP in an inventory (Willo internal documents, 2014).

These forecast oriented products could be divided further into two segments, one with customer agreements regarding replacements, and one without. The replacement agreement function as described in Chapter 4.5, with the customer that is obligated to purchase a specific length of demand that is kept in inventory. The inventory will therefore enable Willo to produce and keep larger amounts of finished goods inventory and by that facilitate faster deliveries to the customers (Sigvardsson, 2015), Figure 21 illustrates different customer agreements.
Customers with requirements regarding deliveries and without replacement agreements are therefore the products that are most critical to plan. In this segment, Willo have some inventory levels for some specific products, while other products are solemnly planned after forecasts received by the customers. These products can therefore be very expensive for Willo, since they cannot sell the products to anyone else than the specific customer. Therefore, if they produce finished products and the customer decides to leave Willo for another supplier, Willo is in the example left with worthless products that has to be scrapped (Sigvardsson, 2015).

4.7.5 Production activity control

The daily activity control is performed by two work leaders, each responsible for one shift. The control consists of making sure the activities are performed when needed and in the right way. Therefore, the daily work incorporates administrative tasks related to personnel scheduling and issues related to the personnel. The production planner decides what to produce, in what machine, and when to produce it but the production activity control will make sure, it is done according to plan. Included in the activity control is to rearrange the workforce to handle short, fast changes in demand. The production activity control is also responsible for making sure the operators report their work and quality related monitoring, where the work leaders has to make sure the products that are being produced are within the product specifications (Sigvardsson, 2015).

4.8 Production planning process at Willo

When one of the following bullet-point occurs, the production planning process will start:

- Customer order is received.
- Forecast from a customer specifies volume of a product to be produced.
• Inventories drops below a specific point for a product.

After the marketing assistant has processed the initial indicator, the production planner releases a manufacturing order for the specific product with a specific volume and delivery date (further explained below). The manufacturing order can start directly or in the near future, depending on delivery date, available capacity and when the customer requests the products (Sigvardsson, 2015).

At Willo, there is also a focus on decreasing the impact of changeovers, meaning that if a large, time-consuming changeover is performed, this could be compensated by producing more products with similar specifications. Even with this focus, it is yet uncommon for Willo to produce products without confirmation or indication from the customer. Since it could occur, and historically have occurred, another point of action and therefore added to the previous three is:

• A similar product is produced after a long changeover.

The determination of when, and in what quantity, a product should be produced in is a decision that is continuously weighted by the production planner, marketing department and production manager. The aim is to find balance between work in progress, resource utilization, and costs for changeovers. These decisions are done differently depending on which customer it is and what aspects that are covered in the customer agreement. Therefore, it is always a trade-off between delivery capability, resource utilization, and capital tide up cost (Sigvardsson, 2015).

During the process of running the production at Willo, raw material inventories are also controlled continuously. Since traceability of products is part of some customer agreements, the handling of raw material is performed in a similar way as the rest of the production. This means that inventory levels are controlled for common raw material with order points, while uncommon material is ordered when a product order is received. Some raw material have, as explained, long lead-times, which can be difficult to account for if a customer agreement not is in place covering a specific time period of raw material (Sigvardsson, 2015).

Another important aspect is manufacturing quantities that are calculated when first offering a price to the customer. Here the calculations regarding economic order quantities and setup times are prized into the product that will be produced. Therefore, batch sizes are important to be kept similar to historical volumes, otherwise new calculations needs to be done (Sigvardsson, 2015).

Production planning process map

Below is a process map, in Figure 22, illustrating activities and decisions when the production planning of a product is performed. The process map starts with a received customer order, forecast, or indication of an inventory drop. These signals are received by the sales department and by the marketing assistant that makes the first check regarding the product.

The first check is done in accordance to a standardized routine where an inspection is done regarding if the product is new or if something is off regarding price or drawing revision,
the marketing assistant forward the order to the marketing manager. The marketing manager will decide and calculate if Willo should accept the order, suggest another price to the customer or what consequences to take regarding drawing changes (Willo internal documents, 2014). The entire process of preparing new products is explained in Chapter 4.6.

If the marketing assistant recognise the product and the standardised routine, show initial data are correct, she forward the order to the production planner. Thereafter the production planner will start to check inventory levels of finished products, too see if the order can be accepted and sent directly. If available inventories are enough, an order confirmation is sent to the customer, while the packaging of products will start. When the products are packed, transport booked and transportations documents are printed, the products are ready for shipment (Sigvardsson, 2015).

If the inventory levels do not cover the order, the actual production planning will begin. This is most common when an order of a customer order oriented product is received, since almost no customer order oriented products are in stock, and updated forecasts usually generate new or changed manufacturing orders. When the decisions have been taken to produce the product, the production planner will then perform a series of activities (Sigvardsson, 2015).

First, the raw material inventories are checked, which could generate a purchase order for new raw material, if there is a lack of raw material. Willo has a process including activities to purchase raw material, this process is not included in this report and will therefore not be explained further (Sigvardsson, 2015).

Next activity, with assumption of available raw material, is to determine which production groups that are affected by the product. To do this, the master data is used specifying in what operations the specific product will be produced. Thereafter the batch size is decided with foundation from EOQ and order size or forecast size. Together batch size and master data of changeover times and operation times of the operations will form the determination of preliminary start time. The start time ensures delivery so the customer receives the products according to the customer agreement, or if no agreement is in pace, as soon as possible (Sigvardsson, 2015).

The questions regarding available capacity will be included next, where the order is checked in accordance to when and in what resources needed to produce the product. If available capacity is enough the order proceed to the next step. Otherwise, if the available capacity do not cover the need for producing are two alternatives present. First, if there are similar machines available, the product could in this case take an alternative route, and secondly if there is capacity that can be released. The capacity can therefore only be released if other orders, less prioritized are moved into the future. To plan this, the planner will cycle back with the orders and once again determine which production groups that will be affected by the order, thereafter reschedule the order into the future (Sigvardsson, 2015).

When capacity is available, the production planner can take the order to the next phase of planning. This phase is where the decision of splitting an order is taken. The splitting can
be performed in two ways, first by using operations overlap and secondly by splitting the entire manufacturing order. By using operations overlap the total lead-time of the order will be reduced, and is therefore used when an order has to be produced as fast as possible. By splitting a manufacturing order, the total lead-time of the entire order will be lengthened but is used to reach the EOQ levels of the different machines. Therefore, when this approach is used, a larger batch is usually produced in the first, main, machine and thereafter separated in smaller batches optimized for EOQ in the next operations. This means, products can be placed and left in WIP after the first machine for some time. Where, for example one of the separated batches will be produced until finished, the other batches are in this case waiting for another order to pull the rest of the products through the last operations (Sigvardsson, 2015).

When all of these decisions have been taken, the planner will generate a start time and delivery time. The customer will receive an order confirmation and the manufacturing order is released to production (Sigvardsson, 2015).
From customer order, forecast or indication to planned product

**Input**
- Customer order received via, mail, fax or post
- Forecast received from customer
- Indication of inventory drop

**Activities**
- Sales department
  - Marketing assistant: Order registration
    - Check if product is new or reoccurring
    - Verify specifications of article data
- Marketing assistant: New product or other concerns?
  - Yes
    - POP meeting
    - Preparation documentation
  - No
    - Warehouse control
- Planner
  - Check inventory levels of the product
    - Yes
    - Check raw material inventories
    - Determine which production groups affected by the order
    - Decide batch size
    - Determine of preliminary start time
    - Is capacity available in the affected production groups or is alternative routes available?
  - No, the product need to be produced
- Planner
  - Check raw material inventories
    - Yes, Operations overlap
    - Is the product in stock?
    - No, can capacity be released?
    - Planning constraints
    - The product need to be produced
    - Determine of splitting sizes
    - Determination of overlap sizes
- Planner
  - Start time is generated
  - Delivery time is generated

**Output**
- Product ready for production
- Order confirmation to customer
- Packaging of product, booking of transport, transportation documents
- Purchase order of raw material
- Manufacturing order is created

**Diagram:** Figure 22: From customer order or forecast to planned product
5. Analysis & mapping results

In this section, the empirical findings will be compared to the theoretical framework, where similarities, opportunities, and obstacles will be highlighted for Willo. The analysis will have the same structure as previous parts of the report where the chapters will concern one part of Willo that together will go through most of the operational organization. Under each part of the analysis, some potential improvement suggestions have been identified, these will be pointed out as “ORG.1.” for example. The numbering system show what area it concern and the number of that particular suggestion. The chapter will present the analysis according to research objective 2.

5.1 Organizational aspects of Willo

Willo has an organization built up around their business concept, which strives towards pleasing their customers, and over time, do a better job than Willo’s competitors do. Important aspects for Willo are; quality, machine utilization, responsibility, open for change, and sharing of knowledge (Willo 2015g). With this foundation, Willo is able to produce small products with high quality to a lower cost compared to their customers and competitors can do by themselves (Willo 2015g). Therefore, the business of manufacture products owned by the customers has become a good and profitable concept for Willo.

Willo has, as described a wide range of customers, all with specific demands. The customers are positioned in different levels of the supply chain, where end users, retailers, lead stakeholders and others as Hill (2005) describe them are included. In the supply chain, the customers are positioned differently. This can directly be linked to the illustration of a supply chain in Figure 9 by Hill (2005), which would place Willo as a tier 1 to 2 supplier. Due to variation of positioning among Willo’s customers, their requirements will therefore also differ accordingly. Willo’s job is then, to adapt and illuminate the aspects they think are the most important for the particular customer.

Willo work today in a good way today to fulfil the demands and requirements necessary for the different customers. However, this makes the knowledge of the personnel significantly important in order to continue with the work. Therefore, a mapping of customer requirements could help a transformation from personnel knowledge to documented routines. Furthermore, another area where Willo are forced to change according to the customers is depending in what market segment the customer operates. The segments all rule under different laws and regulations that the tier suppliers (Willo) have to be in accordance to. If a part of the regulation is overlooked, the lead stakeholder could be charged with fines. Because of this, it is important for Willo to be certified according to the required standards their customers have to follow. Therefore, the market segments; Willo Medtech, Willo Energy and Willo Precision has to be separated regarding how Willo treats them as customers. By doing so Willo can also ensure the transfer of significant knowledge of and to key personnel.

Org.1. Create clear descriptions of what the different market segments demand, regarding documentation, traceability etc., and make sure they are followed.
The overall operational focus of Willo is to supply the best service to their customers, and due to the constant adaptations to customers, it is hard to do. Furthermore, when comparing the focus of Willo to Hill & Hill’s (2009) alternative focus strategies there are in generally, several similarities. Regarding to the different customers, and as Hill & Hill (2009) describes to be common, there are different areas of Willo with different focus. Mainly these areas represent the market segments where, depending on the customer, the focus is to fulfill the customer’s expectations. If a general classification of Willo’s organization is performed, it consequently corresponds to a focus around markets with the alternative of product/market, see illustration in Figure 10. Hill & Hill (2009) describes this alternative focus as, an operations focus consisting of units that serve a specific type of product or customer. The type of focus will move away from the processes and lift up the product or customer instead. This is what Willo has done when they adapt their way of handling the customers. Furthermore, the operational focus of Willo is thereby according to theory and is today working sufficiently regarding a focus on the customer and market segment. The manufacturing plant also strengthens this assumption, which is partly divided according to their different market segments. The market segments are therefore starting to split the manufacturing plant, so one part of the machines are producing products for one segment while other machines manufacture parts for the other segments.

Org.2. Clarify the operational focus of the business, making everyone strives towards the same goal.

This leads to the functional layout of Willo, which has been chosen to facilitate flexibility among the machines and it is therefore easier to appoint and alter the personnel as Miltenburg (2007) describes. Previously this has been the priority when placing new machines. However, before the newly constructed building the machines were placed wherever there was room. When new space was acquired, this has since been changed. Furthermore, this opened a new possibility not to only separate the machines by type, instead a separation could be done in accordance to the market segment the machines served.

By separating the machines according to Miltenburg’s (2007) classification of a job shop and with the operational focus that Hill & Hill (2009) describes, small divisions will be created. Divisions with machines first separated by market segment and secondly by type. The divisions have a specific focus that best suits the target market segment. This is in accordance with what Willo is on their way of doing, with their new space.

Org.3. Study if there are potential gains to separate the machines further according to the market segment they serve, regarding personnel, equipment, and documentation.

As Miltenburg (2007) describes, a job shop has some positive and some negative sides that is important to consider. These positive and negative sides strongly match how Willo’s layout of the production is. First positive aspect is a high flexibility of the manufacturing process (Miltenburg, 2007), which is an important strength that Willo often highlights. Secondly, high utilization among machines and personnel, which is highly prioritized for the production planner at Willo. Last positive side that Miltenburg (2007) describe is low
sensitivity for machine failure, since Willo have many machines that can do similar tasks is this also a characteristic that clearly correspond to the theoretical literature.

Miltenburg (2007) continue with the negative sides of a job shop layout, all of which previously have been highlighted in this study in some way. First, high capital tide up cost with high work in progress, and thereby, secondly, long throughput time. The first two negative sides therefore strongly show that the choice of layout will contribute to have larger storage costs and longer lead-times, which is the case for Willo as well. This is what Shahbazpour & Seidel (2007); Segerstedt (2008); Olhager (2011) describes with conflicts and trade-offs, where companies has to choose what to focus on. Thirdly, Miltenburg (2007) describes a job shop to be hard to plan and administrate the production flow. This negative aspect is one of the aspects to why this study is being performed. Since as Miltenburg (2007) show, the layout of a job shop hinder a company to see the production flow clearly and thereby it is hard to understand and to improve. Lastly, Miltenburg (2007) present the negative side of long transportations between stations and storage. The transportations at Willo have not been included in this study and therefore will it not be commented, however this could be a foundation of future research of Willo’s production.

Org.4. Study the transportations regarding time and distances between operations, as well as the location where products are stored between operations.

The manufacturing plant with the functional layout could hinder Willo further control and overview of the production flow. However, as described this layout has been chosen due to the flexibility it enables. Furthermore, even if the possibility exists to change workflow and produce products in different areas of the production, Willo usually do not do this. Since the operators and machines are not equipped for handling extreme differences of products. Therefore, a part of the flexibility, which was the target, is lost when not in use. This can result in two ways, one suggestion is to keep the layout as it is, to enable future flexibility if needed and not to close any doors. However, if this is chosen the production flow and control will always be hard to manage and oversee as Miltenburg (2007) describes. The second suggestion is to perform a study on what the impacts would be if the functional layout were to be changed. The manufacturing is already somewhat divided regarding the market segment, yet the machines are placed together anyway. If this suggestion is chosen, it can open up possibilities for future improvements regarding efficiency and throughput time. However, this suggestion need products that are similar regarding, specifications and requirements and a somewhat steady demand so machines can be occupied during longer periods. The transportation time and costs can, therefore also be reduced with this approach.

Org.5. Study if there are potential gains to separate the machines further not only according to the market segment they serve, instead separate machines so a cellular layout or a batch flow can be gained.

5.2 Products that Willo manufacture

The products that Willo produce are all considered small. However, between products the size, yearly volume, and number of operations to complete a finished product all have large
variation. A minority of the products have a wide product structure that Segerstedt (2008); Olhager (2011) describes, these product demands an assembly and therefore are the production planning slightly different from the others more common products, with a straight structure. Willo also produces products that are generated both from a customer order, and from a forecast and therefore produced to the warehouse. Furthermore, to account for different sizes, volume, number of operations, structure of the product, and type of order. Willo handle each product individually where the preparation process occur as described in Chapter 4.6. Each product will thereby be planned for production separately, without specific sequencing rules that Doh, et al. 2013 describes. This is presented in mapping of the production planning process in Chapter 4.7. This planning process results in a lot of time and effort consumed, independently regarding the production volume.

Prod.1. Investigate if products must be planned individually, further, study the possibility to plan products together in groups.

At Willo, some products are grouped together into product families as Tatakonda & Wemmerlöv (1992) & Olhager (2011) describes. The grouping has been performed with products, which use a similar production, and operations flow, as Olhager (2011) suggests it to be done. However, this is not included in the ERP software system supporting the production planning and therefore it could easily be overlooked. Because of this, the product families are not used as much as they could. This means that, regarding minimizing the impact of setups and by doing so, produce smaller batches, has room for improvement. To implement one system at Willo, which can handle over 1000 products produced over the last two years, might therefore not be preferable. Since as Olhager (2011) describes, systems that group products together could be costly. However, if simpler methods of how to group products with similar specifications together as Tatakonda & Wemmerlöv (1992) describe could be found, it would be useful for Willo in a production planning perspective. The possibility of grouping products according to aspects outside the product specifications could therefore help clarify and facilitate the production planning. The specifications used for classify products can according to Tatakonda & Wemmerlöv (1992), therefore be increased outside the manufacturing aspects.

Prod.2. Include the existing product families into the ERP software system.

Prod.3. Study if classifications of customers and products could be performed and if so, how this can facilitate the production planning.

5.3 Enterprise resource planning system

At Willo, the ERP software system used is called Jeeves, this system is built up with different modules, which together create a base of information. The software system has therefore the same layout as Segerstedt (2008) & Powell, et al. (2013) describes, with modules each serving a specific purpose. For the production there are some modules commonly used, however the master data module has the base information that most modules use and builds upon. The information in the master data are in Willo’s case the product
information, selection of flow- and production groups, all operations, and product structures if applicable.

Another module used by Willo is the material control, which calculates the available inventories with in and out deliveries for products and raw material. This is used in the planning process, as described in Chapter 4.7, to know if products are in stock so an order can be sent directly to the customer or not. Segerstedt (2008) describes that this module can be used with automatic reorder points to the manufacturing. This is not used at Willo, instead the inventories are monitored, and manufacturing orders released when judged appropriate by the production planner.

\textit{ERP.1. Investigate the possibility of implementing an automatic inventory control system, with reorder points that can be generated when the level drops.}

Furthermore, the material requirements planning, is the module where the production planning is performed. Since there are little planning performed classified as master production scheduling with product families at Willo, the production planning will be performed with finished products directly. This module is therefore used extensively in the software system (Sigvardsson, 2015). Segerstedt (2008) also describes that it is at this stage the manufacturing quantities and available capacity are specified, which is exactly what, according to Sigvardsson (2015), happens at Willo as well.

Shop floor control is the next module used in the software program. Here the operators will report processing time and number of products produced in the system. This can later be used for pricing of products but also to control the available capacity in different operations. This is performed at Willo as Segerstedt (2008) explains it, however not all personnel working with the products use this system. Therefore, it is hard and sometimes impossible to track the products in the production flow. This is a subject for further investigation and a potential improvement in the manufacturing process. With the use today will the monitoring be restrictive to the personnel using the system, which is not everyone. Therefore, by simplify the methods of use can the generated information facilitate a deeper control of the manufacturing and understanding of how long time different products take to process. Moreover, information used for calculate pricing of products can also be incorporated with use of a shop floor control system where the new information correlate to the manufacturing in a larger sense previously not possible. The knowledge of knowing where the products are in the chain will also be improved by a more extensive work with this system.

\textit{ERP.2. Investigate, why the report system is not used by all employees.}

Lastly, the purchasing module is used for all acquisitions related to the manufacturing of products. For example, the raw material is purchased through this module. The suppliers are characterized with lead-times and possible order quantities, these are thereafter used for decision making by the purchaser (Sigvardsson, 2015). Therefore do the theory that Segerstedt (2008) explains, here correspond directly to the empirical findings from Willo.

However, as there is an ERP software system in place, which is in accordance to the theory explained by Segerstedt (2008) & Powell, et al. (2013). Hence should function sufficiently for a general manufacturing company, the support generated from the system is not
enough. This is because some of the specifications in the system are not updated according to today’s manufacturing. Therefore, as the theory assumes all data to be correct are the software systems not representing the reality as well as it could. This results in inaccurate scheduling of products and with manual fixes as correction. For example, an easier overview of the queueing manufacturing orders in the different production groups could benefit the daily production at Willo. Additionally there are functions in the ERP software system, which handles operational overlapping. However, these functions are not used today, even though such overlapping is a common way of manufacture at Willo. Furthermore, there are concerns in the master data of the ERP-system, where the data regarding operation time, changeover time and lead-time are not accurate. This makes it impossible for the production planner to trust the numbers and to get a good production flow between operations and between products in the machines. These are also areas for future investigation for Willo.

**ERP.3. Study what areas that are not correlated between reality and the ERP-system.**

### 5.4 Customer relations

The customer relations at Willo take different forms deepening on market segment and the size of the customer. The customers are therefore handled individually with specific agreements for the different customers. As described, around 80% of the products are produced for 20% of the customers. Furthermore, eight customers are considered the most important customers at Willo these customers can be described as the big 8.

What most of the customers have in common is an agreement with Willo (Backgård, 2015), specifying the regulations and terms of the relationship. This can be linked to what Jonsson & Mattsson (2011) writes, with the division of four types of agreements. The types are divided into; Sales in direct competition, Sales with agreement in competition, Sales with operative agreements, and Sales with strategic agreements. The first type, sales in direct competition, is not extensively used at Willo. This is because Willo wants long-term partners and the process of producing a product for the first time could be cumbersome, therefore Willo usually turn down offers to produce products once without a longer forecasted yearly demand, as explained in the process of how new products are offered to the customers. This type of customer relation will therefore not be used as much, where an offer is sent every time the customer wants products, with new prices and without knowing if Willo will ever do the products again. However, though not preferable, this type exist at Willo, when a customer purchase products seldom, in this case there are no agreed contract but the customer and Willo knows that Willo is the “only supplier” that can deliver these products, meaning there is a high entrance barrier (Backgård, 2015). Furthermore, the customer could have other products with contracts and these products are therefore produced from a strategic viewpoint. However, if a routine for handling these small orders were in place, it could be beneficial for Willo. Since the ability to handle the smaller orders, is uncommon by Willo’s competitors as well (Backgård, 2015).
CR.1. Study the possibility to implement a routine for handling smaller orders, including the handling of the order itself, the manufacturing of smaller batches, and the logistics of a small batch.

The second type of customer relation, sales with agreement in competition, is also not commonly used at Willo. The type is characterized by a standard agreement between the parties concerning prices and delivery terms, however the customer is not obligated to purchase products only from Willo. According to Backgård (2015), the products are produced at Willo usually the entire yearly demand for the customer and therefore not classified as this type.

Third type, sales with operative agreements, is because of this argument used more extensively at Willo. However, as Jonsson & Mattsson (2011) writes, the demand from the customer can be split between two suppliers, a phenomenon that exists at Willo, but for the majority of products Willo is the only supplier. Furthermore, the third type of customer agreement, according to Jonsson & Mattsson (2011), corresponds thereby with many customers of Willo. Since the agreements usually concerns prices, deliveries, quantities, etc., which is negotiated in even periods, but without competition among competitors.

The fourth type will stand for a majority of the products and customer relations at Willo (Backgård, 2015). Since Willo has long-term relationships with their customers and usually are a part of the quality- and product development, these customer relations can therefore be classified as sale against strategic agreements according to Jonsson & Mattsson (2011). For two customers, Willo have appointed available capacity specifically for this product type (Lundqvist, 2015).

Finally, the major part of Willo’s customers can therefore be classified in the last two types of customer relations, according to Jonsson & Mattsson (2011). The customer agreement contracts have, in this situation, no date of cancelation. However, the contracts are revised in even predetermined periods or if a change would occur. These aspects also include the information exchange between Willo and the specific customer, this enable Willo to keep short delivery times and produce according to forecasts given by the customers, according to Jonsson & Mattsson (2011). In Table 6 an overview of the different customer relation types and the percentage of Willo’s products.

CR.2. Clearly document which customers that have different types of agreements and a short description of the general agreement itself for the different customers.

Table 6: Annual turnover of the products compared to customer relation types (Willo internal documents, 20014; Backgård, 2015).

<table>
<thead>
<tr>
<th>Customer relation types</th>
<th>Percentage of Willo’s products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sale in direct competition</td>
<td>2%</td>
</tr>
<tr>
<td>Sales with agreement in competition</td>
<td>10%</td>
</tr>
<tr>
<td>Sales with operative agreements</td>
<td>35%</td>
</tr>
<tr>
<td>Sales with strategic agreements</td>
<td>53%</td>
</tr>
</tbody>
</table>

These specifications are all handled during the process of how new products are being offered and discussed with the customers, as explained in Chapter 4.6. Jonsson & Mattsson
(2011) further describes agreement specifications, which do not correspond directly to Willo’s customer agreements. However, one of the specifications can be linked to Willo, which is:

- Flexible delivery quantities (Jonsson & Mattsson, 2011)

The demand for products could sometimes be difficult to estimate for Willo’s customers. Therefore, one price is often agreed upon when one volume is discussed, if demand changes, a new agreement will be decided. Under this specification, Jonsson & Mattsson (2011) are also describing rules that the customer is obligated to follow if the volume changes. This description could here link the replacement agreements that Willo have with many of their customers. In this regard, the agreement obligates the customer to purchase a specific number of products from the finished goods inventory, a number of the WIP products, and eventually a unit of raw material. The numbers are usually translated from forecasted; one-month worth of finished goods, two-months of WIP, and three- to five month worth of raw material. The amounts are individually set in the specific contracts, which depend on the actual agreement with the customer.

CR.3. Clearly specify active replacement agreements, and which agreement the different customers are obligated to follow.

The customer agreements strongly affect how Willo handle products from a specific customer. Therefore would a complete document with all agreements be beneficial to Willo. In this document, the agreements should be compared with the same specifications.

CR.4. Study the customer agreements and create a collection on all agreements so a comparison between them can be done.

5.5 Production planning

Willo plan the organization in five steps, each step with a separate horizon and focus. The layout of the planning is similar to the theoretical planning horizons presented in Chapter 3.8 by Vollmann (2006), Jacobs et al. (2011) & Olhager (2011). In Figure 23, an illustration shows the five steps of planning at Willo, also shown are the respectively planning horizons from the theoretical framework.
5.5.1 Strategic planning

The strategic planning is performed by the board of directors together with the CEO and owner of Willo (Swanström, 2015). During this process, the theoretical framework, explained by Hill (2005) & Kreitner (2009), is similar to the work performed at Willo. The strategic plan, which specifies where Willo wants to be in the future, is developed and controlled at this level (Swanström, 2015). Furthermore, larger investments are also lifted for discussion, where the board of directors and CEO will decide if the new investments are in accordance with the strategic plan and if the investments help Willo get closer to their long-term goals (Grahn, 2015). The main difference between the strategic planning at Willo and the described theoretical framework is the time horizon. The horizon described in the theory is from 5 years and beyond, where Willo has a time horizon of 2 years and beyond. The main reason to this deviation is that Willo is a smaller company than the theoretical framework aims to describe. Since Willo is a smaller company, the CEO has a greater possibility to monitor and control the organization in more detail, compared to a larger organization.

5.5.2 Sales and operations planning

The sales and operations planning are performed at top management meetings, which occur once every second week, the time horizon covers around 6 months up to 2 years. During these meetings, distribution and sharing of information is a central part of the agenda. The CEO informs if changes have occurred in the strategic plan, and if other decisions have been taken by the board of directors. Furthermore, the strategic plan is broken down into goals for the specific departments. Therefore, this hierarchy level will also correlate with the theoretical framework by the information sharing and presenting the broken down strategic plan described by Vollmann (2005) and Olhager (2011).
However, the time horizon differ from the theoretical framework, which also has the foundation from the size of Willo compared to the general company size that Vollmann (2005) and Olhager (2011) are aiming to describe in their theory.

The procedure of how the sales and operations planning are performed would benefit by the use of clear documentation of the strategic goal, which is broken down in goals for each department. This would facilitate the generation of sub goals and performance indicators in the departments, which are possible to measure.

PP.1. Document the strategic goal and the broken down goals in the different departments. Create clear and measurable goals for each department that are followed in each planning meeting.

The marketing manager, who has the best knowledge of how the customers plan during the next 6 months describes if changes have occurred since the last meeting. In addition, a brief opinion of how the customers could develop over the upcoming years is presented. The four aspects of; demand, supply, volume, and mix that Vollmann (2005) discuss, are included in this discussions. However, as Willo do not have any products of their own, the discussions of product mix will have another focus related to Willo’s different customers instead. General suggestions regarding resources are later discussed with the potential demand as base. Decisions, regarding investments in form of personnel and machines are thereafter taken.

One difference between Willo’s sales and operations planning and the theoretical framework that Vollmann (2005) and Olhager (2011) describe is the use of forecasts of product families. Forecasts, which later are broken down in the master production scheduling and material requirement planning of specific products, by using a bill of material or similar structures (Vollmann, 2005; Olhager, 2011). Willo receive forecasts from their largest customers, however these forecasts are generally not on product family level, instead they are on specific product level. This means, product families are generally not so important for Willo since the planning of the production can be more detailed at a higher level. On the other hand, the information received could be too detailed, which results in too much information and since there are no categories to group products together, issues of grasping the big picture. As described, Willo have produced around 1000 different products over the last two years in three market segments. Important aspects for Willo is to detect and interpret changes in demand of specific products, however, this can be hard to do, with too small changes or overreaction as consequence. The potential that can be used instead of product families are the orders received by the different customers itself, which is a routine that is used at Willo today. Willo use the aggregated economic value of the customer orders, which are measured every month to compare with historical values.

PP.2. Study if potential exists to create product families in a larger scale, and if so, what potential benefits that would bring in comparison to the economic value of the customer orders.

5.5.3 Master production scheduling
The main planning meetings, which are similar to master production scheduling in the theoretical framework, where the focus is on planning the actual production at Willo. The
meetings consist of the production manager, marketing manager, and the production planner. The meetings are not specifically documented and occur around every second month, or when requested. During the meetings, the marketing manager presents the latest information from the customers, how the forecasts changed since the last meeting, and if new customers are in scope. According to Segerstedt (2008), the master production scheduling should break down the sales and operations plan and link it to the production. This is happening during the master production scheduling meetings but it is not the main agenda. Since, the production planner is not included in the top management team where the sales and operations planning occur, the main planning meetings is therefore more or less a duplication from those meetings. The differences being, a stronger focus towards the production and more exact how to manufacture the amounts forecasted by the customers. The procedure incorporates discussions with the horizon of around 6 months, regarding available capacity within the flow groups. Simpler calculations are performed to see how the forecasts affect the flow group’s available capacity during the period. The calculations however only concern some major products during the period. For other products no calculations are performed, instead they are planned for manufacturing when an order or forecast is received. With this as base, decisions regarding number of shifts and how many hours per week the flow groups have to be available are taken. If large deviations exists between the general calculations and the available capacity, suggested solutions is discussed and lifted to the sales and operations planning level.

PP.3. Create a standardized process or routine, which can be used during the master production scheduling meetings. Furthermore, document the meetings according to the routine.

PP.4. Increase the occurrence of the master production scheduling meetings and perform them in even intervals.

The planning procedure can, according to Segerstedt (2008) instead be performed by using net requirements planning or cover time planning. This means, there are large possible improvements in this planning horizon by the usage of net requirements planning. Since the resources needed to fulfil the demand are a highly discussed area at Willo today, would a system that calculates the actual need according to orders and forecasts received of great importance. The prerequisites for net requirements planning are, according to Segerstedt (2008):

- A clear and updated production plan for end products
- Structures of end products, specifying sub products
- Accurate inventory levels
- Accurate lead-times for all articles

However, as described, Willo do not use this method today, the reasons to this decision are twofold; no previous experience with net requirements planning, and Willo do not fulfil all requirements presented by Segerstedt (2008). The last reason is particularly important, where problems regarding accurate lead-times for all products, setup times, and cycle times have previously been described as a problem for the production planner. Therefore, this opens up a new potential study for future research.
5.5.4 Material requirement planning

The planning at this horizon level has been mapped in the data collection. The production planner is responsible for the material requirement planning, where the aim at Willo is to keep the resource utilization of machines high. The planning horizon stretches from daily- to monthly plans including small fixes and prioritization among manufacturing orders. At this planning level, the individual products are planned in specific machines at specific times. This means, the level of detail is increased significantly from the other planning horizons. According to Segerstedt (2008), and the theoretical framework, the aim of material requirement planning could thereby be to:

- Keep promised delivery times
- Follow the master production schedule
- Make sure that material, resources and equipment is available at the right time in the right place
- Keep the level of the production steady
- Minimize the costs for work in progress

Compared to Willo’s aim of keeping the resource utilization of machines high, there are some aspects of these five more important to the production planner (Sigvardsson, 2015). Together with the framework, the top three important aspects for Willo’s material requirements planning are:

1. Keep promised delivery times
2. High machine resource utilization
3. Make sure that material, resources and equipment is available at the right time in the right place

Keep promised delivery times, is among these prioritized on top, Sigvardsson (2015) explains this with it is implied in the day-to-day production planning. However, the long-term focus is to keep a high resource utilization. The remaining three are not considered equally important:

- Follow the master production schedule
- Keep the level of the production steady
- Minimize the costs for work in progress

According to Sigvardsson (2015), other factors generally control these aspects, and therefore, are they not monitored as carefully and prioritized as high. Since Willo only produce products after a customer order or a forecast has been received, are products not produced just because keeping the production level steady or to keep the master production schedule if deviations have occurred (Sigvardsson, 2015).

PP.6. Investigate the possibility of decreasing the work in progress, by clarify which products that are kept as work in progress and why.
From the identified differences of following the master production schedule, keep the level of production steady, and minimize the costs for work in progress. The master production schedule cannot be followed since there is no dedicated schedule performed. Keep the level of production steady is also hard since Willo, as explained, do not have any own products, which can be produced in advance. Therefore can production level smoothing be hard to perform. However, minimize the costs for work in progress, can be utilized in a larger scale than today at Willo, though it would be easier to do if the production flow was easier to follow and control. Therefore, are many of the identified potential opportunities connected and would together create a more extensive possible control over production levels and orders flowing through the plant.

Furthermore, there are no support functions from the ERP-system, which can monitor the resource utilization in a sufficient way. The system show the queue of any given production group during a set interval of days, however, there are no capacity from the resources to compare too. This opens up a future possible study.

**PP.7. Investigate the possibility of implementing a feature, which monitors the production groups capacity and capacity utilization.**

### 5.5.5 Production activity control

The production activity control is performed by two work leaders at Willo, each responsible for one shift. This planning horizon has the shortest aspect of time, where it is represented by the single shift to the weekly production. Responsibilities of the work leaders are among others to make sure the material requirements plan are performed according to plan and that the operators report their work. The production activity control, correlate with the theoretical framework describes by Segerstedt (2008) and Olhager (2011) in a clear way. They describe how the closet planning horizon should focus on operators and how, when and where the products should be produced. However, the theoretical framework brings forward how the reports generated by the operators could be used as a base for future changes. This has not been prioritized at Willo, since as described in Chapter 1 the focus has historically been to produce as good and as fast as possible. The reports from the operators are where production- and changeover times are entered. These reports can, according to the theoretical framework be used as foundation for potential, future improvements. By the implemented use of these reports, the ERP-system could gain a vast improvement and further open up the potential of implementing net requirements planning in the future. Therefore, leave this room for future improvements and a potentiality for future research.

**PP.8. Study the potential benefits if reports are performed as described by the management, and present a plan of how Willo can get to this point.**

### 5.6 Summary of the potential improvements for Willo.

In this section, a summary of the bullet points are presented, generated from each of the previous chapters in the analysis, sorted in chronological order. These potential improvements have been identified as areas where Willo have an opportunity for improvement. The potential improvements should be considered as suggestions generated
from this study. Some of these potential improvements will be chosen for further research in the next chapter where others will be mentioned further in Chapter 7.

Organizational aspects of Willo

Org.1. Create clear descriptions of what the different market segments demand, regarding documentation, traceability etc., and make sure they are followed.

Org.2. Clarify the operational focus of the business, making everyone strives towards the same goal.

Org.3. Study if there are potential gains to separate the machines further according to the market segment they serve, regarding personnel, equipment, and documentation.

Org.4. Study the transportations regarding time and distances between operations, as well as the location where products are stored between operations.

Org.5. Study if there are potential gains to separate the machines further not only according to the market segment they serve, instead separate machines so a cellular layout or a batch flow can be gained.

Products that Willo manufacture

Prod.1. Investigate if products must be planned individually, further, study the possibility to plan products together in groups.

Prod.2. Include the existing product families into the ERP software system.

Prod.3. Study if classifications of customers and products could be performed and if so, how this can facilitate the production planning.

Enterprise resource planning system

ERP.1. Investigate the possibility of implementing an automatic inventory control system, with reorder points that can be generated when the level drops.

ERP.2. Investigate, why the report system is not used by all employees.

ERP.3. Study what areas that are not correlated between reality and the ERP-system.

Customer relations

CR.1. Study the possibility to implement a routine for handling smaller orders, including the handling of the order itself, the manufacturing of smaller batches, and the logistics of a small batch.

CR.2. Clearly document which customers that have different types of agreements and a short description of the general agreement itself for the different customers.

CR.3. Clearly specify active replacement agreements, and which agreement the different customers are obligated to follow.

CR.4. Study the customer agreements and create a collection on all agreements so a comparison between them can be done.
Production planning

**PP.1.** Document the strategic goal and the broken down goals in the different departments. Create clear and measurable goals for each department that are followed in each planning meeting.

**PP.2.** Study if potential exists to create product families in a larger scale, and if so, what potential benefits that would bring in comparison to the economic value of the customer orders.

**PP.3.** Create a standardized process or routine, which can be used during the master production scheduling meetings. Furthermore, document the meetings according to the routine.

**PP.4.** Increase the occurrence of the master production scheduling meetings and perform them in even intervals.

**PP.5.** Study what aspects that are needed to implement net requirements planning, and perform an analysis on where improvements are necessary.

**PP.6.** Investigate the possibility of decreasing the work in progress, by clarify which products that are kept as work in progress and why.

**PP.7.** Investigate the possibility of implementing a feature, which monitors the production groups capacity and capacity utilization.

**PP.8.** Study the potential benefits if reports are performed as described by the management, and present a plan of how Willo can get to this point.
6. Classification modelling

In this section, a few potential improvements from Chapter 5 have been chosen for further investigation, according to research objective 3. All chosen potential improvements concern the planning of products, but in different aspects. A model will be created where topics regarding customers and products are identified. Under each topic, several specifications will further create a classification model. Information has been gathered for each of the specifications for the chosen customers and products, information which can be used to classify products into groups. These groups can be formed of products without visible similarities, however, the products share similar manufactural specifications and can therefore be planned in a similar way. This classification model has been created in order to help Willo to find a solution to the chosen potential improvements in the future.

6.1 Introduction and background to the classification model

The production planning process takes, as described in previous chapters, a lot of time at Willo, and is today very cumbersome. The production planner has to plan each manufacturing order separately for all of their products (Sigvardsson, 2015). This is not favourable for Willo since they have produced around 1000 different products during the last two years, where every product usually have several orders and every manufacturing order have been manually planned in the ERP-system. Further problems and discussions arise when the production planner, marketing manager, production manager, or the work leaders have something that troubles them. Due to this, discussions regarding; in what machine the products should be produced in, prioritizations between products, and the allocation of resources necessary to produce the products according to plan, will be discussed frequently. Furthermore, the specific customer that owns the product will strongly affect the decisions made regarding these questions, because of the many customer agreements that exist. Furthermore, the customer agreements could be hard to locate and interpret, since everyone is structured and expressed differently. This result in decisions made without sufficient information, by the concerned personnel regarding what to prioritize, and focus on. If Willo want the possibility to continue to grow as the management team were striving towards, a system that facilitates the decision making process would be helpful.

To manage the problems a model has been created, including aspects important to base the decisions on facts instead of intuition. The model origin from the customer agreements and by adding the financial aspects, product specifications, and ability to produce, the model will be formulated. By collecting information first regarding the customers and later the products into the model, groups can be generated to classify products in. With these groups of classifications as base, and with the new information it brings, products can be compared, similarities found, and decisions that are based on facts can be made, making the hard decisions mentioned above easier to handle.

The classification model further group customers/products together that have the same prerequisites and specifications, hence should be planned in a similar way. This information
can be used for further research when trying to optimize a group of products or one classification that share similar specifications, which previously have not been possible.

### 6.2 Potential improvements to include

From the analysis and mapping results, some improvement suggestions have been identified and presented in Chapter 5.6. From these improvement suggestions have a few been chosen for further study. The chosen suggestions all share similarities that can be solved or improved by facilitating the manufacturing and planning of the products at Willo. Some of these potential improvements will be directly linked to the classification model, while others will be affected by the solution of the first potential improvements, giving a domino effect. The chosen potential improvements are:

- **Org.1.** Create clear descriptions of what the different market segments demand, regarding documentation, traceability etc., and make sure they are followed.

- **Org.3.** Study if there are potential gains to separate the machines further according to the market segment they serve, regarding personnel, equipment, and documentation.

- **Prod.1.** Investigate if products must be planned individually, further, study the possibility to plan products together in groups.

- **Prod.2.** Include the existing product families into the ERP software system.

- **Prod.3.** Study if classifications of customers and products could be performed and if so, how this can facilitate the production planning.

- **ERP.1.** Investigate the possibility of implementing an automatic inventory control system, with reorder points that can be generated when the level drops.

- **ERP.3.** Study what areas that are not correlated between reality and the ERP-system.

- **CR.2.** Clearly document which customers that have different types of agreements and a short description of the general agreement itself for the different customers.

- **CR.3.** Clearly specify active replacement agreements, and which agreement the different customers are obligated to follow.

- **CR.4.** Study the customer agreements and create a collection on all agreements so a comparison between them can be done.

- **PP.2.** Study if potential exists to create product families in a larger scale, and if so, what potential benefits that would bring in comparison to the economic value of the customer orders.

- **PP.6.** Investigate the possibility of decreasing the work in progress, by clarify which products that are kept as work in progress and why.
6.3 Classification model

In this section, a model will be introduced and explained, which can be used to classify Willo’s customers and products into groups, regarding different specifications. According to Tatikonda & Wemmerlöv (1992), products can be grouped together with specifications outside of the regular physical aspects of a product. Where the physical aspects include the shape, type, size, form, and function of a product normally used when grouping products according to Tatikonda & Wemmerlöv (1992) & Olhager (2011). The specifications will instead include the manufactural aspects of a product, such as production flow, yearly volume, customer agreements, etc. These specifications used for the classifications will be performed on Willo’s eight main customers and on four products produced for each of these customers. This limitation is due to the large amount of products and customers Willo produce to, making the information gathering process otherwise very time consuming.

As Tatikonda & Wemmerlöv (1992) describe, a model that can be modular is preferable, since it can be adapted for new products and new circumstances without major reconstruction. Furthermore, Tatikonda & Wemmerlöv (1992) state the importance to determine the purpose and objective of the classification. For this model, the purpose is to facilitate the production planning process, by assisting decisions, which today lack facts and are very time consuming. Additionally, another purpose is to enable future improvements for Willo on an identified product group, this group could with the help of the model, include products from several departments and customers, yet still share similarities, and therefore all benefit from a single improvement. Furthermore, the objectives are mainly to:

- Facilitate the production planning process.
- Develop a modular method for classifying products into different groups, which consist of products with similar specifications.
- The groups should facilitate an easier and faster production planning process that can handle more products in the future.

With these three objectives as base, the model will be formed from six main topics. The topics represent areas, which have an origin from the data collection process in the report, generated from several unstructured interviews and observations together with many employees throughout Willo’s organization. All topics and later, specifications have been discussed and agreed upon together with key stakeholders at Willo. The topics influence the production planning process in different ways, some in a more clear way than others do. These topics are:

- Financial specifications
- Customer agreements
- Product specifications
- Internal ability to produce
- Actual flow of production
- Raw material
Specifications will be formulated from each topic, which also have been chosen after several interviews and close collaboration with the personnel at Willo to include aspects that otherwise easily can be overlooked. Some specifications influence one type of products more than others do which is done intentionally and will be used in the classification process. To divide the model, the first two topics, financial specifications, and customer agreements will only concern the customers. Since these topics and the consisting specifications can be generalized for the products under each customer. Furthermore, the last four topics will only concern the specific products and not the customer itself. This is done because the specifications all differ from the products within the same customer. Further, the specifications will later will be used to generate clusters to which the products can be sorted and grouped by.

6.3.1 Customer classification specifications

This part describes the first two main topics together with the specifications for each one. These topics will only be classified regarding the customer itself and not on specific product level.

The first of the two topics in this section is financial specifications and under this area, there are two specifications. Below each will be listed together with a short explanation:

- **Market segment.** Specify in which market segment the customer operate.
- **Annual turnover at Willo.** Specify the annual turnover per customer, at Willo in percentage, (later censored).

Secondly the specifications regarding the customer agreements, which consist of six specifications:

- **If customer leaves forecast.** State with yes or no if the customer leaves forecasts for their products.
- **What forecasts, month, quarter, year.** Determine the intervals of the forecasts,
- **Historical dependability of the forecasts (1-5).** Specify if the forecasts have previously been accurate with a scale 1-5 with 5 representing the best dependability.
- **Promised lead-time.** Specify if the customer agreement includes a promised lead-time until delivery, stated with interval of calendar days.
- **Replacement of inventories.** Specify if the customer agreement include that the customer is obligated to purchase products before changes are enabled to the product. Yes or no.
- **Which type of replacement, raw material, WIP, finished products.** Specify the type of replacement the customer is obligated to purchase.

The customer classification specifications can be seen together in Table 7 below.
### Table 7: Customer classification specifications

<table>
<thead>
<tr>
<th>Financial specifications</th>
<th>Market segment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Annual turnover at Willo, (later censored)</td>
</tr>
</tbody>
</table>

| Customer agreements       | If customer leaves forecast                                                     |
|                          | What forecasts, month, quarter, year                                            |
|                          | Historical dependability of the forecasts (1-5)                                |
|                          | Promised lead-time                                                             |
|                          | Replacement of inventories                                                     |
|                          | Which type replacements, raw material, WIP, finished products                  |

#### 6.3.2 Product classification specifications

In this second section the last four of the main topics will be described and the specifications within. These topics will only be classified regarding the specific product and not on the customer. Consisting of ten specifications, first are specifications under the topic product specifications.

- **Product family.** Specify if a product family exist, and if so, to which family the product belongs.
- **Margin.** The margin of a particular product in percent, (later censored).
- **Complexity.** Specify the number of components necessary for completing a finished product.
- **Type of product.** Specify if the product is a customer product or an intermediate product
- **Purchased product.** State if the product is purchased, yes or if no, is it produced at Willo.
- **Promised lead-time.** Specify the lead-time promised to the customer in the customer agreement, for the particular product in calendar days.
- **State in life cycle.** Specify in what state the product is, in its life cycle, varying from; Introduction, Growth, Maturity, and Decline.
- **Yearly demand (pcs).** Specify the forecasted yearly demand or last years production, in numbers per product.
- **Rounding value (pcs).** Could also be called packaging size, where a number specifies the addition that multiplied enlarges the order, for example 50, 100, 150, etc. with 50 as rounding value.
- **Mean customer order (pcs).** Specify the average amount of the customer orders during 2014/2015.
- **Batch handling.** Specify if special handling is needed, where traceability is necessary from raw material to finished product.
- **Drawing revision.** Specify the identification number it is on the specific drawing of the product, which is used to make sure the classifications is up to date.
Secondly, internal ability to produce, consisting of eight specifications. These specifications include the resources, times, and how the product is produced. Furthermore, these specifications also focus on the product itself.

- **Required resources.** List the resources (production groups) necessary to produce the product.
- **Number of operations.** Specify the number of operations to complete a finished product.
- **Scheduled overlap.** Specify if any overlap are scheduled (Yes or No), in form of splitting an active order in one or two machines with the purpose of shortening the throughput time.
- **Calculated quantity, EOQ (pcs).** Calculated quantity of the first main machine is here specified.
- **Changeover time.** Specify the planned changeover time for the first main machine.
- **Production lead-time.** Specify the days needed to produce a manufacturing order with the quantity of EOQ, and without delay, according to the ERP-system in calendar days.
- **Mean manufacturing order (pcs).** Specify the average quantity generated from the actual manufacturing orders during 2014 & 2015.
- **Result from previous runs.** Specify the difference from previous manufacturing order runs, and planned duration time and cost in percentage. Included are; changeover time and operation time in the ERP-system, and the costs generated by each operation. The percentage is 100% when previous runs are as planned, above generates a better result (less cost of producing the product) than planed and below a worse result (higher cost of producing the product).

Third topic concerns the actual flow of production at Willo where the information has been collected from the ERP-system and the operators’ reports after each operation.

- **Actual application of overlap.** If overlap actually has occurred during the production of the particular product, and if so, what type of overlap? Yes 1, Yes 2, or No.
- **Production flow.** A continue and interpretation of the above specification. The alternatives are; Real overlap, Operational overlap, and Straight flow.
  - **Real overlap:** Products split up early and are traveling one by one or in other smaller batches from machine to machine. The delivery to warehouse is also split in several occasions (Yes 1).
  - **Operational overlap:** Products split up, and the batch can be processed in two or more machines during the same time. However, the products are gathered at one operation (often when hardening occur) and finally put into the warehouse as a whole batch again (Yes 2).
  - **Straight flow:** Products travels together in the batch from start until finished (No).
- **Based on manufacturing order size.** Specifies where the information has been collected from, by listing the quantity of the orders. By doing so, can the orders be located again if necessary.
The fourth and final main topic is specification regarding raw material for the specific product.

- **Lead-time for raw material.** Specify the length of the lead-time for the raw material for the specific product, in calendar days.

The product classification specifications of the last three topics and the specifications have been plotted into Table 8, below.

*Table 8: Product classification specifications*

<table>
<thead>
<tr>
<th>Product specifications</th>
<th>Required resources</th>
<th>Actual flow of production</th>
<th>Raw material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product family</td>
<td></td>
<td>Actual application of overlap</td>
<td>Lead-time for raw material</td>
</tr>
<tr>
<td>Margin (censored)</td>
<td></td>
<td>Production flow</td>
<td></td>
</tr>
<tr>
<td>Complexity</td>
<td></td>
<td>Based on manufacturing order size</td>
<td></td>
</tr>
<tr>
<td>Type of product</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purchased product</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Promised lead-time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>State in life cycle</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yearly demand (pcs)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rounding value (pcs)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean customer order (pcs)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Batch handling</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Drawing revision</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Internal ability to produce</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scheduled overlap</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calculated quantity, EOQ (pcs)</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Changeover time</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Production lead-time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean manufacturing order (pcs)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Result from previous runs</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 6.4 Classification of customers

The first part of the base model will be filled up with information from some of the customers of Willo. The chosen customers are eight of Willo’s largest customers and stands for the majority of the annual turnover. The information has been gathered from the ERP-system, internal documents, and together with several semi- and unstructured interviews
with key stakeholders. Appendix 1 shows further details of dates and questions under classification of products.

Due to sensitive information, some specifications have been left blanked or have been altered in this version. For example, the eight companies will be named Company A-H, in the tables below, and the annual turnover at Willo will be left blank. Moreover, some cells are marked with N/A, which represent, non-existing specification, lack of specific information, or if the customer agreement do not support the particular specification.

Furthermore, the table is split in two for legibility reasons. Company A-D is presented in the first, Table 9, and Company E-H in the second Table 10.

*Table 9: Classification model, Customers A-D*

<table>
<thead>
<tr>
<th>Classification topic</th>
<th>Specification</th>
<th>Company A</th>
<th>Company B</th>
<th>Company C</th>
<th>Company D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial specifications</td>
<td>Market segment</td>
<td>Precision</td>
<td>Medtech</td>
<td>Precision</td>
<td>Precision</td>
</tr>
<tr>
<td>Annual turnover at Willo</td>
<td>If customer leaves forecast</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes, delivery plan</td>
<td>Yes</td>
</tr>
<tr>
<td>Customer agreements</td>
<td>What forecasts, month, quarter, year</td>
<td>Month, quarter, half year, and year. Updated each month</td>
<td>Month, quarter, 5 months, year. Updated each month, year updates every quarter</td>
<td>Delivery plan, half year, Updated twice per week</td>
<td>Yearly</td>
</tr>
<tr>
<td></td>
<td>Historical dependability of the forecasts (1-5)</td>
<td>3</td>
<td>4</td>
<td>4,5</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Promised lead-time</td>
<td>7-56 days</td>
<td>20 days or delivery plan</td>
<td>Delivery plan</td>
<td>According to throughput time</td>
</tr>
<tr>
<td></td>
<td>Replacement of inventories</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Which type replacements, raw material, WIP, finished products</td>
<td>12 Weeks of finished or semi finished products</td>
<td>3 months, according to delivery plan</td>
<td>Raw material 9-12 Weeks, WIP 5-8 Weeks, finished products 1-4 Weeks</td>
<td>The forecasted products for the coming 16 weeks</td>
</tr>
</tbody>
</table>
Results from the customers show that six of the eight customers leave forecasts, however, historically have the forecasts not been very dependable. Four of the customers have lead-time requirements with an interval ranging from 7-112 calendar days. Two customers leave one form of delivery plan where one of these (Customer C) specifies the actual dates of delivery that is used instead of promised lead-times. The last three customers have dynamic lead-times depending on actual workload of the machines and the order quantity, this is decided when the order is received.

Furthermore, six of the customers have some sort of agreement regarding replacements of inventories if changes would occur. This means, as explained, if a drawing is changed the customer first need to purchase a specific amount of “old” products before the “new” changes take place. This is very helpful for Willo regarding the promised lead-times and the ability to keep products in WIP.

With this information, some general similarities can be identified:

- Customers that leave forecasts and have agreements of replacement of inventories, Customer D
- Customers that leave forecasts, have agreements regarding replacement of inventories and that have promised lead-times, Customer A, B, C, E & F
- Customers that do not leave forecasts and without replacement of inventories, Customers G & H

<table>
<thead>
<tr>
<th>Classification topic</th>
<th>Specification</th>
<th>Company E</th>
<th>Company F</th>
<th>Company G</th>
<th>Company H</th>
</tr>
</thead>
<tbody>
<tr>
<td>Financial specifications</td>
<td>Market segment</td>
<td>Precision</td>
<td>Energy</td>
<td>Precision</td>
<td>Precision</td>
</tr>
<tr>
<td></td>
<td>Annual turnover at Willo</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Customer agreements</td>
<td>If customer leaves forecast</td>
<td>Yes</td>
<td>Yes, delivery plan</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>What forecasts, month, quarter, year</td>
<td>Quarter, half year, year. Updated every month</td>
<td>Half year, year. Updated every quarter</td>
<td>Quarter, year. Updated each month</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Historical dependability of the forecasts</td>
<td>2,5</td>
<td>2</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Promised lead-time</td>
<td>7-60 days</td>
<td>112 days</td>
<td>According to throughput time</td>
<td>According to throughput time</td>
</tr>
<tr>
<td></td>
<td>Replacement of inventories</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Which type replacements, raw material, WIP, finished products</td>
<td>The forecasted products for the coming 16 weeks</td>
<td>6 months, according to set delivery plan</td>
<td>N/A</td>
<td>N/A</td>
</tr>
</tbody>
</table>
6.5 Classification of products

By continue with the base model and fill in the information regarding a small selection of products for each customer will the second part be complete. Four products have been chosen for each customer, where the selection has concerned products with different yearly demands and yearly turnover. By selecting four products with different yearly demands and turnover, the result will potentially generate four products with different specifications and the first start of product groups. These products have been selected together with concerned personnel, however, mostly together with the production planner, marketing manager, and marketing assistant. The information has been gathered from the ERP-system, internal documents, and together with several semi- and unstructured interviews with key persons. Appendix 1 show further details of dates, and questions under classification of products.

In this section, sensitive information exists in form of product name and margin. This information has been changed to Product A1-H4, and the margins have intentionally been left blanked. Furthermore, some cells are marked with N/A, which represent, non-existing specification for the target product, lack of specific information, or if the customer agreement do not support the particular specification.

The table is split eight times to form one table per customer for legibility reasons, where each company is shown with the four products in each table. Presented in Appendix 3-10 are the four products per customer. By listing all the customers and the products with the same specifications in the classification model, a comparison can be created. The comparison shows some characteristics listed below:

- None of the products are today included in any product family.
- The margins have been removed due to confidentiality reasons.
- The complexity of the products is low, 28 of the 32 products are single products without assembly. For the products with more than one part; Product H4 and G1, have 2 components, Product F1 has 3, and finally Product E1 have 4 components.
- The majority are customer products, however, some products have been classified as intermediate products. These will be modified and further processed under a different product name.
- The promised lead-time varies a lot for some of the products from the same customer.
- State in the life cycle differs and the product ranges from introduction to decline.
- Yearly demand differs from the products under the same customer.
- Number of operations ranges from 1 to 17.
- None of the products has scheduled overlap included in the ERP-system and by that included in the planning process.
- The changeover times are relatively high ranging from 0 to 18 hours.
- Production lead-times have large variations between the products ranging from 1 to 164 calendar days, based on a manufacturing order with the quantity of EOQ and without delay.
- Mean manufacturing order, can in some cases, differ a lot from the EOQ for the same product.
• Results from previous runs are in general around 100%. However, some outliers exist, one at 48%, one at 23%, and one at 173%.
• Actual application of overlap shows that the majority of the products are actually produced by some type of overlap.
• The lead-times for raw material differ from 7 to 168 days.

With these characteristics, the comparison shows large variations both between products in general and products produced for the same customer. However, some similarities can be identified, which form aspects of characteristics for the products. These similarities are listed below, together with the concerned products.

• Products with a complexity larger than 1, Product E1, F1, G1 & H4
• Products with a complexity of 1, Product A1-4, B1-4, C1-4, D1-4, E2-4, F2-4, G2-4 & H1-3
• Products that are customer products, Product A1-4, B1-4, C1-4, D1-4, E1-4, F1-4, G1, G3 & H3
• Products that are intermediate products, Product G2, G4, H1, H2 & H4
• Yearly demand of 1 – 5000, Product A2-4, B4, C3, C4, D3, D4 & E1-4
• Yearly demand of 5001 – 20 000, Product A1, B2, B3, C1, C2, D2, F2-4 & H3
• Yearly demand of 20 001 and up, Product B1, D1, F1, G1-4, H1, H2 & H4
• Requirements regarding batch handling, Product A1-4, B1-4, C1-4, D1, D2, D4, E1-4 & F1-4
• No requirements regarding batch handling, Product D3, G1-4 & H1-4
• Promised lead-time of 1 – 7 days, A3
• Promised lead-time of 8 – 30 days, A1, A2, B3, B4, E1 & E3
• Promised lead-time of 31 days and up, A4, B1, B2, E2 & E4
• Production lead-time of 1 – 7 days, C1, C4, G4
• Production lead-time of 8 – 30 days, A1, A3, A4, B1, B2, B4, C3, D3, E1, E3, E4, F3, F4, G1, H2-4
• Production lead-time of 31 days and up, A2, B3, C2, D1, D2, D4, E2, F1, F2, G2, G3, H1
• Lead-time for raw material of 1- 30 days, A2-4, C1-4, E3,
• Lead-time for raw material of 31 - 60 days, B3, B4, D4, E1, E4
• Lead-time for raw material of 61 days and up, A1, B1, B2, D1-3, E2, G1-4, H1-4
• Actual application of overlap, with real overlap, E1, F1
• Actual application of overlap, with operational overlap, A3, B1-4, C2, C4, D1, D4, E2, E4, F2-4
• No application of overlap, A1, A2, A4, C1, C3, D2, D3, E3, G1-4, H1-4

With further analysis of the specifications, some additional characteristics can be identified by performing simple calculations:
• Promised lead-time – production lead-time (EOQ)
• Mean manufacturing order / mean customer order
• Yearly demand / mean customer order
• Yearly demand / mean manufacturing order
- Yearly demand / EOQ

By doing these calculations shown in Appendix 11, specific problem areas can be highlighted so efforts can be put into investigating the reason of occurrence. For example, the products coloured in red in Appendix 11, show when the promised lead-time is shorter than the production lead-time, these products clearly needs inventories. However, products with a positive number of days could be controlled so limited amounts are put in inventory. Further, another example of a highlighted area is why a product, D1 are produced 12 times per year, yet only sold 7 time during the same year. Furthermore, A1 is produced 2 times per year yet sold 30 times to the customer, while the customer agreement only obligates the customer to purchase 12 weeks of finished products if changes occur.

6.6 Analysis of results

The results from the topics with specifications both from the customer’s Table 9 & 10, and from all the products shown in Appendix 3-11. These specifications will here further be processed. By splitting the specifications into two or three alternatives, every product can be marked with an X for conformance to one of the specific alternatives. Some of the products do not correspond to either of the alternatives of a specification, when this has occurred the box have been left blank. By performing this marking on the specifications, a table will be formed. The table consist of rows that show the specifications and columns that show all the products where X marks if a specific product belong to a specification alternative this is shown in Table 11. This table have been performed to facilitating further development of the classification model.
<table>
<thead>
<tr>
<th>Specification alternatives</th>
<th>A1</th>
<th>A2</th>
<th>A3</th>
<th>A4</th>
<th>B1</th>
<th>B2</th>
<th>B3</th>
<th>B4</th>
<th>C1</th>
<th>C2</th>
<th>C3</th>
<th>C4</th>
<th>D1</th>
<th>D2</th>
<th>D3</th>
<th>D4</th>
<th>E1</th>
<th>E2</th>
<th>E3</th>
<th>E4</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
<th>F4</th>
<th>G1</th>
<th>G2</th>
<th>G3</th>
<th>G4</th>
<th>H1</th>
<th>H2</th>
<th>H3</th>
<th>H4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Products with a complexity larger than 1</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Products with a complexity of 1</td>
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<tr>
<td>Products that are customer products</td>
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<td>Products that are intermediate products</td>
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<td>Yearly demand of 5001 – 20 000</td>
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<td>Yearly demand of 20 001 and up</td>
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As shown in Table 11, and as explained above, several products share specification characteristics. Meanwhile, several outliers keep the products from forming clear groups of product similarity. However, Table 11 enables the possibility to performing a production flow analysis. When Olhager (2011) presents the concept of production flow analysis it represents products and machines, in which the products are processed. However, the approach of grouping products to their individual manufactural specifications according to Tatikonda & Wemmerlöv (1992) can here be applied. By applying a combination of Tatikonda & Wemmerlöv’s (1992) grouping technology with their “classification and coding” and Olhager’s production flow analysis, the products can further be assessed and formed in groups, which can be used for classifications. As Olhager, 2011 describes, a production flow analysis can be performed with two different approaches, one by moving rows and columns to find similarities between products, and one that uses a formula to calculate the resource similarity between two products. In this analysis, the method of calculating will mainly be used.

The approach of calculating a resource similarity or specification similarity between products will here be applied. The calculations are done by counting how many specifications a product correlates with (how many X there is in a column) and how many specifications two products share (how many X’s two products share). With these numbers, the following formula is applied (Olhager, 2011):

\[
RS_{ij} = 0.5 \left( \frac{N_{ij}}{N_i} + \frac{N_{ij}}{N_j} \right)
\]

Where:
- \( RS_{ij} \) = Resource similarity of product i and j
- \( N_{ij} \) = Number of resource types that both product i & j need
- \( N_i \) = Number of resource types that are needed for product i
- \( N_j \) = Number of resource types that are needed for product j

The results from these calculations are presented in Table 12, and show how much two products share their resources, or in this particular case, share their specifications. This is done with an index number, which is a number from 0 to 1 where 0 is no specification similarity and 1 is full specification similarity. As can be seen in the table, a specification similarity of 0.85 and above has been marked with a green colour to clarify where the highest indexes are. As seen in Table 12, high index numbers can be seen in clusters, but with several outliers.
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Table 1: Resource similarity, production flow analysis
However, the overall result in Table 12 is hard to grasp, instead the indexes have been used to form a dendogram shown in Figure 24. In this Figure, the correlation is illustrated with lines. The thin dotted horizontal lines of 0,00 to 1,00 make the dendogram’s index levels, where the columns show the different products. The thick lines illustrate the specification similarities and on which index level it is. For example, product F3 and F4 has an index level of 1 and C3 and E3 has a specification similarity with an index of 0,93. Product groups are formed when two or more products correlate at a specific index level, while more and more products join when the index level drops.

Figure 24: Dendogram of product specification similarity

A limit to form groups can be set to different index levels, Olhager (2011) suggests a limit of 0,80. However, to form more groups in this study the limit of products with a specification similarity of 0,85 and higher are considered to be a part of a group. By doing so, three main groups will be formed. However, there will be some products left outside of these limits and will therefore be excluded from the three main groups.

To start, F3 and F4 share their specifications where an index of 1 is received. Meanwhile the second group is received by C2 and F2 with an index of 0,96. Together these two groups, form a group at index 0,92, to which D2 joins at index level 0,88. At level 0,86 A1 will also be considered to be a part of this group.

C3 and E3 has a correlation of specifications of 0,93, but when the index level reaches 0,87 product B4, A2, A3, and C4 join and form a larger group. At index level 0,85 the larger group of F3, F4, C2, F2, D2, and A1 is added to the group, with the addition of C1.

B1, E2, and E4 will form a group of specification similarity at level 0,87.

G1, H4 and H2 form a group at index level 0,92 while, G3, G2, G4, H1, and H3 form another group also at 0,92. Together these will form a larger group at index 0,85.
This gives three groups:

1. F3, F4, C2, F2, D2, A1, C3, E3, B4, A2, A3, C4, and C1
2. B1, E2, E4
3. G1, H4, H2, G3, G2, G4, H1, H3

All three market segments Willo operates in are represented in the first group. The second group include products from Willo Precision and Willo Medtech, where group three only include products from Willo Precision. Additionally there are some products with a specification similarity lower than 0.85 these are specified here.

- B3, added to the first group at 0.83
- D1, added to the first and second group as they merge at 0.80
- A4, added to the first and second group as they merge at 0.80
- B2, added to the first and second group as they merge at 0.80
- F1, added to the largest merged group at 0.76
- E1 added to the largest merged group at 0.76
- D4, added to the largest merged group at 0.75
- D3, added after the third group is merged into the two other groups, merge at 0.72, E1 added at 0.68

At 0.68 do D3 lastly finalize the products into a shared product group. The result where all products share the same product family is usually lower than 0.68. The result from the analysis differ because of this type of analysis is usually performed on products and their machines needed to process them, as Olhager (2011) explains. Since this analysis includes the specifications related to the manufacturing of the products it is significantly higher.

As explained above, a production flow analysis can be performed in two ways, now when the way of calculating indexes and relationships among products have been performed the other alternative will here further illustrate the similarities.

By moving the columns to match the dendogram, another visualization of the groups can be found. This can be seen in Table 13, were the original table (Table 11) has been altered. The rows have been changed to keep the common specifications in the centre of the table, where the number of products that are specified with a particular specification gradually decrease throughout the interval.

The table show three product groups marked with boxes, there are the same as explained above. Furthermore, products that are not marked with a box indicates products with a lower specification similarity of below 0.85. With this limitation, no products are considered a sufficiently good match to form a group.
### Table 13: Illustration of production flow analysis of the products

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*Note: The table utilizes X's to indicate the presence or absence of a condition or parameter based on the production flow analysis of the products.*
6.7 Conclusions from the analysis

The dendogram and Table 13 together give an illustration of products, which share specifications regarding how they are manufactured at Willo. The analysis shows a result of three product groups, or groups that products can be classified by. However, there are several products not included in these three groups. The reason being that those particular products do not have the amount of shared specifications needed to find a good match between the chosen products. For clarification, the products for this analysis have been chosen because of their difference and because they can represent a larger segment of products at Willo. This means, if the study were to be performed on all of Willo’s customers and on all of their products, the results would potentially be different. Probably more specifications would be included and many more product groups used for classification would to be identified. Potentially making the proportion of products without a group smaller. However, if a large amount of products remains to be unrelated, these should be investigated further to why large deviations of manufacturing exist.

By using this classification model as base, Willo can be able to perform the necessary information gathering and the analysis to form the larger tables needed to get full overview of the products and processes. By doing so, more groups will potentially be found of many similarities between different products.

The objectives of the classification model were to:

- Facilitate the production planning process.
- Develop a modular method for classifying products into different groups, which consist of products with similar specifications.
- The groups should facilitate an easier and faster production planning process that can handle more products in the future.

As the model is presented in this report, there is still work to be performed in order to reach these objectives completely. The model will give more detailed information about a product than before, and additionally specifies products similar to the particular product. Which means that the production planner can get ideas of how other, similar products are being planned and processed during the planning process. Additionally, the production planner will be able to base more decisions on facts, when the information is presented in the model. For example, Willo has previously not a document of all of their customer agreements with clear similarities and differences among their customers and products. However, the model will not at this point, facilitate an easier and faster production planning process that can handle more products. There are still more products that needs to be processed and included in the analysis, which has been left for Willo to include in the existing model.

In the future, and the real potential for this classification model is by choosing one product group and by analysing the movements through the factory and specifications regarding quantities, the production planner and the production manager will have the possibility to improve that target group. By choosing one product group, focus can be set regarding what type of improvement needed for this particular group. For example, if one group have a steady demand and behaves similar throughout the production, a system could be
implemented that creates manufacturing/purchasing orders automatically when a reorder point is reached. By doing so, the production planner will have more time to focus on the products and the manufacturing orders that specifically need more time.

Furthermore, the specifications could be weighted for importance this would give a result which can be closer to a single persons needs of a classification system. Since different specifications are more important depending on the specific stakeholder that will use the model. For example, the specification of yearly demand and the three alternatives of 1 – 5000 pieces, 5001 – 20 000 pieces, and 20 001 and up, can be considered to be more important for the production planner than if the product is a customer product or an intermediate product. With the same example, the marketing manager can consider the intermediate products to be irrelevant for him making the customer product more important than the yearly demand. With this example as base, a modular weighting option could be a positive function to add when implementing the model on all of Willo’s products.

In Chapter 5.7 a summary of potential improvements for Willo is presented, some of these improvements have been highlighted in this chapter. These improvements have been highlighted since they potentiality were positively affected by this classification model. The selected potential improvements are here listed with an explanation of how it would be affected in different degrees if this classification model were to be fully implemented at Willo:

Org.1. Create clear descriptions of what the different market segments demand, regarding documentation, traceability etc., and make sure they are followed.

Willo have all of the customer’s demands included in the different segments documented in the customer agreements. However, these agreements could be hard to find, overlook, and to know if additional conditions have been included later. This is because all of them differ from customer to customer and could be old which makes them harder to locate and to confirm conformance. With the classification model, every customer will be specified and compared with the foundation from the same base model. The new information this would bring are a new perspective of what similarities, and differences exist between the customers and market segments. Additionally this can open up room for improvement, regarding similar products that are considered to be in the same group during the analysis, yet produced for different market segments. However, the model itself will not make sure that Willo keep fulfilling the demands for all of their market segments.

Org.3. Study if there are potential gains to separate the machines further according to the market segment they serve, regarding personnel, equipment, and documentation.

Willo use three types of production flow, real overlap, operational overlap, and straight flow, as described depending on customer agreements and product specifications. These production flows have previously not been documented at Willo, and by analysing historical production flows information regarding how products flow through the factory can be found. This information will further be compared by using the classification model to find similarities between how products are processed in different machines. By doing so the results can potentially open up discussions regarding similar products but with
different production flow. However, additional analysis is needed in order to calculate potential gains for separating machines according to new aspects.

Prod.1. Investigate if products must be planned individually, further, study the possibility to plan products together in groups.

Willo plan every product and every manufacturing/purchasing order individually today, since this is not only time consuming it also hinders further development due to limitations to the amount of work the production planner is able to do. By classifying products according to the classification model, Willo will be able to compare and create product groups, which consist of products with similar specifications. Potentially some of these groups consist of products with a steady demand and a simple production flow, which could be controlled by a system that makes sure the inventory levels are within specified limits. A system like this can create manufacturing/purchase orders automatically when a specific reorder point is reached, which opens up room for additional products in the future.

Prod.2. Include the existing product families into the ERP software system.

Willo have, as previously explained, some product families today, however, these only exist in excel sheets and are not used when planning a manufacturing order. By using the classification model, the product families will be included in the same comparison as the rest of the aspects. However, the ERP software system is not currently supporting the classification model. This is a main part where Willo have work left until the model is integrated into their organization.

Prod.3. Study if classifications of customers and products could be performed and if so, how this can facilitate the production planning.

The part of the suggested improvement regarding study if there is a possibility to perform a classification of customers and products have been answered with this chapter. Additionally there are potential gains and obstacles discussed together with what parts left to include in the model and further development of the classification model for Willo. The classification model can facilitate the production planning in several levels, one that include the possibility to improve by using the additional information generated by the comparison of customers and products. Another level is by grouping products that have similar manufactural specifications. By doing so they can be used for improving handling the large amount of manufacturing orders, or control the production flow by changing how some of the products are being produced. Additionally with more and more reliable information the production planner, marketing manager, and production manager can base a larger amount of decisions regarding the products and production on facts, which will help them control the manufacturing and personnel in an easier way.

ERP.1. Investigate the possibility of implementing an automatic inventory control system, with reorder points that can be generated when the level drops.

By using the classification model and including all of Willo’s customers and products, a new possibility of handling specific group arises. One part of Willo’s products has steady supply and demand without a complicated production flow. With further analysis there could be
a possibility of creating a system that crates manufacturing orders automatically. However, the ERP software system has to be included in this analysis. Development of a system for handling the new information from the classification model has to be performed. The system should be included in the ERP software system and visualise important information when needed. This has been left for future research.

CR.2. Clearly document which customers that have different types of agreements and a short description of the general agreement itself for the different customers.

The documentation of different types of agreements has been performed during the information gathering process. Information regarding different types of agreements and what aspects the agreements include has been divided into key specifications. These specifications can be seen in the classification tables over the customers and are therefore included in the classification model. However, there are several customers left to process to gain an overview of all customer agreements at Willo. A short summary of the agreements have not been performed, if considered necessary this will be left for future work at Willo.

CR.3. Clearly specify active replacement agreements, and which agreement the different customers are obligated to follow.

This improvement suggestion strongly correlates with CR.2. The solution will be found together or after CR.2. Therefore, this improvement suggestion will be considered to have a domino effect.

CR.4. Study the customer agreements and create a collection on all agreements so a comparison between them can be done.

This improvement suggestion also strongly correlates with CR.2. The solution will be found together or after CR.2. if the classification model is used. Therefore, this improvement suggestion will be considered to have a domino effect at this point.

PP.2. Study if potential exists to create product families in a larger scale, and if so, what potential benefits that would bring in comparison to the economic value of the customer orders.

By introducing the classification model, the analysis will potentially show products to be similar regarding to how they are being manufactured, which will indicate products that can be clustered into groups. The groups will be formed with no consideration of which market segment the products are in. Therefore, a result of similar specifications, which are commonly occurring in the different groups, can be shown. Without previously discussed benefits of creating product groups or product families are the possibility to measure the families over longer periods of time. This could give larger insight in product families that are increasing and others that are decreasing. Since this has previously not been possible to perform with over 1000 products can new focus areas be created.

PP.6. Investigate the possibility of decreasing the work in progress, by clarify which products that are kept as work in progress and why.

When performing the information gathering process necessary for the classification model, the historical manufacturing orders have been used. These clearly show the production
flow of a specific product from operation to operation and if a batch been located at one operation longer than the operation itself. To truly answering the question of why some products become stuck along the way, individual analysis has to be performed. However, the classification model will help identifying these products as a specification illustrated in the tables. After the information has been gathered and the analysis been performed improvements can be done in order to control the production in a more efficient way, with low delay and waiting times.

Another aspect of decreasing the work in progress is by knowing the customer agreements, regarding replacements if changes to the product were to be performed. With this information, the stakeholders know if work in progress is favourable or not. Additionally by implementing automatic manufacturing/purchasing orders, discussed in other improvement suggestion, a lower work in progress can be reached.
7. Conclusions & recommendations

In this chapter, the purpose of the report is presented together with the four research objectives. Conclusions for each of the research objectives with future recommendations for Willo will be presented. Finally, a reflection of the report, discussions regarding the methodology and the results of the study are presented.

7.1 Summary of the research

As a reminder the purpose and goal of this study is to:

Study how the current production planning process is conducted at Willo, to map and suggest future improvements. The goal is to develop and present a method for classifying products into different groups. The classifications should facilitate an easier and faster production planning process that can handle more products in the future.

From the purpose, four research objectives will further specify and point out the aim of this report:

1. Initially map the planning process and identify processes that influence the production plan at Willo.
2. Analyse the identified differences between Willo’s planning focus and time horizons to theoretical literature.
3. Develop a method for classifying products into different groups, which can be used for production planning purposes.
4. Suggest future improvements to Willo regarding the production planning process with foundation from the presented classification method and identified differences to the literature.

Theories regarding production planning, focus operations, customer relations, among others, and the case study at Willo have been presented in the report. Comparisons between theory and selected areas of Willo’s organization have been performed to find potential areas for improvements. Some of these identified areas have been selected for further analysis where a classification model has been developed. This model has been tested with Willo’s eight largest customers and four products from each customer. With the aim to find similarities among products regarding specifications usually not used when forming product families. This classification has been performed to facilitate the production planning and to enable Willo to handle more products in the future.

7.2 Conclusions of the research

Generated from the purpose of the study are four research objectives, which will be concluded in this section.

The first research objective was to initially map the planning process and identify processes that influence the production plan at Willo. The results have been gathered during the data collection phase, explained in Chapter 2. However, a description of the planning process can be seen in Chapter 4 together with a process map of the production planning process.
The overall planning process includes five planning levels with overlapping time horizons and focuses, all with different processes that influence a main plan to facilitate the complete goal of Willo’s business. These processes are explained in Chapter 4 under each planning level. However, the main production planning is first initiated in the fourth level of planning, which is also the level that has been further detailed. After identifying all aspects and decisions regarding why and when a manufacturing order is planned and released to the production at Willo, a process map can be formed. With a formulation of the process map, a deeper understanding of the process has been created. Furthermore, the process map has therefore facilitated improvement suggestions on specific areas without restructuring the entire process.

The second research objective was to analyse the identified differences between Willo’s planning focus and time horizons to theoretical literature. These have been identified during the analysis phase of the study, explained in Chapter 2. However, the result of the analysis has been presented in Chapter 5.5, where the Figure 23 shows main differences of time horizon in the five levels of planning. The main difference to theory regarding time horizons has been linked to the size of the organization of Willo in Chapter 5.5. The theory often relates to a larger organizational size when forming models, and therefore more complex organization for top management to control. At Willo, with a smaller organization, the top management have the possibility to control the operations in lower levels, which enables top management a closer control and thereby lower time horizons.

The planning focus of the horizons is mainly in accordance to theory, where main business goals are broken down into more specific department goals. However, in lower levels of planning horizon, some of the actual activities explained in theory are not used at Willo today. This leaves room for improvements where, for example, an implementation of net requirements planning would be prioritized, together with functionality of monitoring capacity utilization for the production groups. The comparison of Willo’s planning processes and theory have also helped the personnel involved to understand how the levels are connected, why specific activities, which can be seen to be irrelevant for the person performing the activity are very important for personnel in other levels of planning, and how improvements on one level can facilitate another. Examples of activities are reports that the operators do after a batch is finished at that specific machine. Where the operator does not gain more information of that activity, the production planner will on the other hand, be able to monitor manufacturing orders to make sure the customer order is fulfilled.

The third research objective was to develop a method for classifying products into different groups, which can be used for production planning purposes. This objective has been developed during the analysis phase, explained in Chapter 2. The results from the development can be seen in Chapter 6, which has the origin from some of the identified improvement suggestions from Chapter 5 and have therefore been chosen for further research. Results from the introduction of a classification model can help fulfilling these chosen improvement suggestions and to facilitate an easier and faster production planning process. Also a production planning process that can handle more products in the future. The model consists of six topics with several sub specifications under each topic, in total there are 32 specifications, which have been generated in close collaboration with the
personnel at Willo. The model have been introduced and tested on Willo’s eight largest customers and four products per customer. The customers and products have all been specified according to the same model and can furthermore be classified according to their specification similarity with a developed model of production flow analysis explained in Chapter 6.

The specification similarity has been analysed, were the results show three clear product groups, and several products either right outside the group or further away. However, if more products were to be included in the model, the result will potentially generate more similarities and more product groups. Before Willo can implement the classification model there are work left for future research consisting of specifying all products into the existing model. Furthermore, the calculations, which form the similarity indexes and therefore the product groups, have to include all products to receive new groups. The classification model has been prepared for these further developments in order to classify all the products.

The benefits of implementing a classification model that group products together have been discussed in Chapter 6. However, to clarify, by having groups of products that have similar manufactural specifications, the production planner will gain more information when planning products, which facilitates a faster decision making processes. Additionally, some products could potentially be identified with improvements regarding production, control, or flow through the factory. Therefore is there a good possibility that more products can be improved as well, by finding the product group to which they belong. This means one specific product group consisting of different products from several market segments, however with similar manufactural specifications can be analysed and improved together.

The fourth research objective was to suggest future improvements to Willo regarding the production planning process with foundation from the presented classification method, and identified differences to the literature. This objective has been developed during the discussion and recommendations phase presented in Chapter 2. Results from the development is presented in Chapter 5, were some of the improvement suggestions have been chosen for further research in Chapter 6. Below are improvements suggestions regarding production planning listed together with improvements generated by the classification method separated with headlines of were at Willo the impact of the improvement is.

Organizational aspects of Willo

Org.1. Create clear descriptions of what the different market segments demand, regarding documentation, traceability etc., and make sure they are followed.

Org.2. Clarify the operational focus of the business, making everyone strives towards the same goal.

Org.3. Study if there are potential gains to separate the machines further according to the market segment they serve, regarding personnel, equipment, and documentation.
Org.4. Study the transportations regarding time and distances between operations, as well as the location where products are stored between operations.

Org.5. Study if there are potential gains to separate the machines further not only according to the market segment they serve, instead separate machines so a cellular layout or a batch flow can be gained.

Products that Willo manufacture

Prod.1. Investigate if products must be planned individually, further, study the possibility to plan products together in groups.

Prod.2. Include the existing product families into the ERP software system.

Prod.3. Study if classifications of customers and products could be performed and if so, how this can facilitate the production planning.

Enterprise resource planning system

ERP.1. Investigate the possibility of implementing an automatic inventory control system, with reorder points that can be generated when the level drops.

ERP.2. Investigate, why the report system is not used by all employees.

ERP.3. Study what areas that are not correlated between reality and the ERP-system.

Customer relations

CR.1. Study the possibility to implement a routine for handling smaller orders, including the handling of the order itself, the manufacturing of smaller batches, and the logistics of a small batch.

CR.2. Clearly document which customers that have different types of agreements and a short description of the general agreement itself for the different customers.

CR.3. Clearly specify active replacement agreements, and which agreement the different customers are obligated to follow.

CR.4. Study the customer agreements and create a collection on all agreements so a comparison between them can be done.

Production planning

PP.1. Document the strategic goal and the broken down goals in the different departments. Create clear and measurable goals for each department that are followed in each planning meeting.

PP.2. Study if potential exists to create product families in a larger scale, and if so, what potential benefits that would bring in comparison to the economic value of the customer orders.

PP.3. Create a standardized process or routine, which can be used during the master production scheduling meetings. Furthermore, document the meetings according to the routine.
PP.4. Increase the occurrence of the master production scheduling meetings and perform them in even intervals.

PP.5. Study what aspects that are needed to implement net requirements planning, and perform an analysis on where improvements are necessary.

PP.6. Investigate the possibility of decreasing the work in progress, by clarify which products that are kept as work in progress and why.

PP.7. Investigate the possibility of implementing a feature, which monitors the production groups capacity and capacity utilization.

PP.8. Study the potential benefits if reports are performed as described by the management, and present a plan of how Willo can get to this point.

7.3 Recommendations to Willo and future research

Willo have received potential improvements that together will help them get closer to their overall business goal of 10% annual growth. These suggestions have been developed over time during the study, and most of the improvements will make the organization easier to overview and control. Information regarding customer segments, operational focus, customer agreements, and goals for the departments are very important, especially for, but not only, the personnel working with the specific subjects each day. Therefore, the organization can learn more from person to person, by study and documenting many aspects that now only exist in some person’s heads. By doing so, the organization can grow along with the turnover.

Furthermore, several potential improvements need further investigation or analysis, where the suggestions are recommended topics to study for Willo. Example of where this study have identified improvement potential are; internal logistics, classification and grouping of products, production report system, alignment between reality and ERP-system, implementation of net requirements planning, and monitoring capacity utilization. These topics are some of the improvement potentials that need further study before clear recommendations can be concluded.

However, to facilitate the implementation of all improvement suggestions, basic functions first need to be prioritized. As described in earlier chapters. During the data collection phase, when mapping the production planning process and during the information gathering process when developing the classification model, several unconformities have been identified. These unconformities are basic specifications regarding EOQ, process time, changeover time, lead-time for raw material, etc. in the ERP-software system. This means, specifications in the ERP-system are old or inaccurate and the real process time for example, could be either longer or shorter than specified in the system. Identified areas during the study have been corrected. However, there are a lot more information that needs to be revised and adjusted. Personnel at Willo are aware of these issues, however, the vast impact of the effect have been overlooked. Mostly since the production planner manually adjust many of the variables for a particular manufacturing order, with a time consuming effects both for the order and for the planner. Due to this, the first
recommendation to Willo is to make sure that the most important variables are accurate in the ERP-system.

Furthermore, Willo would benefit from implementing a net requirements planning system. The reason why they have not done so yet is mainly, because unconformities between the ERP-system and reality. If this will be improved, an implementation of net requirements planning system will enable the production planner to gain an overview of all products that needs to be processed, and when they need to be finished. This information is manually controlled at Willo today, and with around 1000 products and several manufacturing orders per product per year is it a very time consuming task. The potential of this implementation would have a major improvement, and further possibility for growth for Willo.

Third recommendation for Willo is to study the possibility to monitor daily, monthly, and future planned, utilization of capacity on all production groups, together and separately. By doing so resources can be moved between production groups or priorities can be done between manufacturing orders, to adjust the capacity and to make sure there are enough machines and personnel to complete a customer order. The possibility to monitor the capacity utilization will also help when strategic decisions are made, regarding resources of machines and personnel.

Fourth recommendation is to monitor all inventories continuously. These inventories could be of raw material, work in progress, and finished goods. Willo does this today, however, there are still inventory levels that is not allied with the ERP-system. Furthermore, Willo would benefit from specifying not only the amount of the goods, in addition specifying where the goods are located with a specified shelf or storage location. By doing so, time wasted on searching for a specific order can be reduced while the amounts in the ERP-system are more accurate. This recommendation would include updating the way of working regarding reports operators do when an operation is complete. However, there is a good opportunity to always making sure that the inventories are located where, when, and in the amount needed.

These four recommendations will help Willo to obtain control and overview of the products and production. The classification model facilitates a further development and opportunity for improvement to their systems and way of working, which will be important as the turnover grows. By improving the overall support for the production planning process, Willo will be able to handle more products in the future and can therefore keep up with a growing demand. Willo are on a good path of reaching their business goals, and with recommendations discussed in this study, are Willo able to strive past obstacles and grow continuously as a whole organization.

7.4 Reflections of the study
To gain the best possible information, several interviews, observations, documents, and the ERP-system have been used. Initially the aim of the study was to map the production planning and suggest ideas for improvements. However, parallel to the mapping was another focus to strive forward and suggesting improvements to one of the production
planner’s main obstacle, which was the large amount of products and manufacturing orders. At this point, the focus was moved beyond some of the obstacles identified during mapping of the current situation. The obstacles would be solved by the four main recommendations presented in Chapter 7.3 for Willo. In this new focus, the aim of the study shifted several times until the idea of finding similarities among products according to, how they were produced, why are they produced in a specific way, and how a customer agreement control how a product is manufactured were found together with personnel at Willo.

The decision of choosing the classification model for further research was made in accordance to main stakeholders at Willo. The information needed for the model was later gathered by documents, the ERP-system, and interviews. However, when the information was not specified or documented in any way, have assumptions been made by the production planner, marketing manager, or other personnel at Willo. This constitutes a risk of receiving wrong information, and is therefore the main risk in the study. However, everything included in this study have when possible, been crosschecked with other personnel to make sure high degree of accuracy.

Furthermore, after the decision of choosing the classification model, there have been difficulties in developing a model, capable of handling the large amount of specifications without losing overview, and the ability to compare the findings later. The choice of including two theories and by doing so, creating the ability to calculate the specification similarity made large difference. The results could, after this choice be shown in a dendogram, where the specification similarity easily can be seen and at what indexes product groups are formed.

By developing the classification model, some generalisations to other similar companies can be done. The model applies the combination of two theories presented by Tadikonda & Wemmerlöv (1992) and Olhager (2011). By doing so the possibility of grouping products together outside the size, form, or function of a product will be opened. Where the theory of classify products according to manufactural aspects presented by Tadikonda & Wemmerlöv (1992) and the possibility to analyse the results with production flow analysis according to Olhager (2011). With this combination and application, a small contribution of theory has been done where further research can be performed.

Concluding the study and interesting for the target company, Willo would be to visit a similar “tier 1 to 2” supplier, a supplier that have made a journey of increasing their turnover and therefore forced to adapt their organization to cope with obstacles that arise. A visit like this would help Willo to see a large picture of how a company have taken an organization to another level. New support functions, which previously were not needed, could need to be established. The accuracy of information will become more important as the business grows together with the accessibility to that information. This would probably mean many changes in how personnel work today, however, by doing so new doors could be opened.
References


Willo internal documents, 2014. Växjö: Willo AB


### Appendix 1: List of interviewees

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<td>Kristina Sigvardsson</td>
<td>Production planner</td>
<td>2015-02-09, 2015-03-16, 2015-04-09, 2015-05-23</td>
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<td>Semi- and unstructured interviews in person</td>
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<td>Peter Grahn</td>
<td>Administrative manager</td>
<td>2015-02-09, 2015-03-24, 2015-04-10, 2015-05-17</td>
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<td>Semi- and unstructured interviews in person</td>
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<td>Jennie Forzén</td>
<td>Logistics</td>
<td>2015-02-11</td>
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<td>Johan Blomster</td>
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<td>2015-02-12, 2015-03-24, 2015-05-28</td>
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<td>Bengt Swanström</td>
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<td>Quality control work leader</td>
<td>2015-02-19</td>
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<td>Dates</td>
<td>Questions</td>
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<td>Adis Mujadizc</td>
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<td>General planning questions, Production process questions</td>
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<td>Peter Hultkvist</td>
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Appendix 2: List of interview questions

These questions have been discussed during the interviews with some exceptions depending on; the aim of the interview, and the person interviewed.

**General planning questions**

- What, in general could function better regarding the production planning?
- Is there something specific that you think would be good if it existed or were expressed?
- What is your general vision of how the production planning could be performed and how would it look like in that case?
- What do you think is necessary to facilitate the production planning?
  - What needs to be studied?
- What is the most important question or subject for you?

**Planning process questions**

- How are the products planned for manufacturing today?
- What happens when an order is received?
- How are forecasts handled?
- How does the process differ between a customer order and a forecast?
- When and what happens when an order is rescheduled?
- How does the prioritization of manufacturing orders work?
- Do you have any other general suggestions or opinions regarding the production planning, and how it is performed today?
- Reports from operators?
- Documentation and information flow?
- Documentation to find errors in the production flow?
- How do you think the production planning would work with an increase of turnover?
Production process questions

- What do you think regarding flow- and production groups?
  - Are there some groups that could be split up or that need to be evaluated?
- How do you think the daily control could be easier to follow?
  - How do you think regarding a system, which prioritize manufacturing orders?
    - Do you see any potential problems with such system?
- Do you have ideas to illuminate manufacturing orders, which represent the first offer to a customer in the production flow?
  - Do you see any potential problems with separating the new with the regular manufacturing orders?

Price offering questions

- How are products offered to the customers today?
- How does the process of preparing a product for manufacturing look?
- How is the master data calculated?
- How often is it evaluated?

Classifications of products

- How do you think classifications of products can help the production planning?
- What aspects should be included in the specifications?
- How you think classifications could help the production planning when the turnover increases?
- What customers should be included?
- How many products, and which products, should be included from each customer?
### Appendix 3: Product classification, Company A

<table>
<thead>
<tr>
<th>Company A</th>
<th>Classification specification</th>
<th>Product A1</th>
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<th>Product A3</th>
<th>Product A4</th>
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<td>1</td>
<td>1</td>
<td>1</td>
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<td>No</td>
<td>No</td>
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<td>35 days</td>
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<td>Maturity</td>
<td>Maturity</td>
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<td>Yes</td>
<td>Yes</td>
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<td>Drawing revision</td>
<td>4</td>
<td>1</td>
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<td>1</td>
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</table>

| | Number of operations | 8 | 11 | 12 | 11 |
| | Scheduled overlap | Not scheduled | Not scheduled | Not scheduled | Not scheduled |
| | Calculated quantity, EOQ (pcs) | 8 000 | 1 500 | 650 | 500 |
| | Changeover time | 4h | 15h | 15h | 18h |
| | Production lead-time | 28 days | 39 days | 25 days | 30 days |
| | Mean manufacturing order (pcs) | 8 422 | 1 552 | 656 | 590 |
| | Result from previous runs | 108% | 86% | 124% | 98% |

| Internal ability to produce | Actual application of overlap | No | No | Yes 2 | No |
| | Production flow | Straight flow | Straight flow | Operational overlap | Straight flow |
| | Based on manufacturing order size | 8000, 8000 | 1500 | 650, 650 | 450 |
| | Raw material | Lead-time for raw material | 84 days | 28 days | 14 days | 28 days |
### Appendix 4: Product classification, Company B

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<th>Company B</th>
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<th>Product B1</th>
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<td>Yes 2</td>
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## Appendix 5: Product classification, Company C

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<th>C16A, Lego10, Trml, CS1, CS1, Barb, Pack, QC, Lager</th>
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## Appendix 6: Product classification, Company D

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<td>N/A, according to throughput time</td>
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### Internal ability to produce

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### Actual flow of production

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<td>Operational overlap</td>
</tr>
</tbody>
</table>

### Based on manufacturing order size

| Based on manufacturing order size | 15500, 11000, 16000, 8500 | 2100, 2450, 1750, 4600 | 382, 371, 650, 750, 140, 180, 320 | 100 |

### Raw material

| Lead-time for raw material | 168 days | 168 days | 168 days | 56 days |

---

123
## Appendix 7: Product classification, Company E

<table>
<thead>
<tr>
<th>Company F</th>
<th>Classification specification</th>
<th>Product E1</th>
<th>Product E2</th>
<th>Product E3</th>
<th>Product E4</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>Product family</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Margin</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td>1</td>
<td>1</td>
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<tr>
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<td>Type of product</td>
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<td>Customer product</td>
<td>Customer product</td>
<td>Customer product</td>
</tr>
<tr>
<td></td>
<td>Purchased product</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td></td>
<td>Promised lead-time</td>
<td>10 days</td>
<td>84 days</td>
<td>21 days</td>
<td>56 days</td>
</tr>
<tr>
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<td>State in life cycle</td>
<td>Maturity</td>
<td>Maturity</td>
<td>Maturity</td>
<td>Maturity</td>
</tr>
<tr>
<td></td>
<td>Yearly demand (pcs)</td>
<td>3 574</td>
<td>1 320</td>
<td>1 238</td>
<td>154</td>
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<td>0</td>
<td>0</td>
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<td>Yes</td>
<td>Yes</td>
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<tr>
<td></td>
<td>Drawing revision</td>
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<td>1</td>
<td>1</td>
<td>1</td>
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<table>
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<tr>
<th>Internal ability to produce</th>
<th>Required resources</th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of operations</td>
<td>9</td>
<td>17</td>
<td>9</td>
<td>16</td>
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<tr>
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<td>Not scheduled</td>
<td>Not scheduled</td>
<td>Not scheduled</td>
</tr>
<tr>
<td></td>
<td>Calculated quantity, EOQ (pcs)</td>
<td>1 000</td>
<td>400</td>
<td>150</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Changeover time</td>
<td>8h</td>
<td>0h</td>
<td>6h</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Production lead-time</td>
<td>15 days</td>
<td>65 days</td>
<td>10 days</td>
<td>11 days</td>
</tr>
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<td>Mean manufacturing order (pcs)</td>
<td>396</td>
<td>405</td>
<td>234</td>
<td>69</td>
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<tr>
<td></td>
<td>Result from previous runs</td>
<td>84%</td>
<td>112%</td>
<td>73%</td>
<td>173%</td>
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<table>
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<th>Actual application of overlap</th>
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<th>Yes 2</th>
<th>No</th>
<th>Yes 2</th>
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<td>Real overlap</td>
<td>Operational overlap</td>
<td>Straight flow</td>
<td>Operational overlap, Gnist</td>
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<td>Based on manufacturing order size</td>
<td>300, 500, 400</td>
<td>380, 400, 450</td>
<td>200, 150, 250</td>
<td>58, 75</td>
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<td>Raw material</td>
<td>Lead-time for raw material</td>
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<td>84 days</td>
<td>28 days</td>
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### Appendix 8: Product classification, Company F

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<td>1</td>
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<td>Type of product</td>
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<td>Customer product</td>
<td>Customer product</td>
<td>Customer product</td>
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<td>No</td>
<td>No</td>
<td>No</td>
</tr>
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<td></td>
<td>Promised lead-time</td>
<td>N/A, according to delivery plan</td>
<td>N/A, according to delivery plan</td>
<td>N/A, according to delivery plan</td>
<td>N/A, according to delivery plan</td>
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<td>Maturity</td>
<td>Maturity</td>
<td>Decline</td>
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<td>Yearly demand (pcs)</td>
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<td>8 203</td>
<td>3 500</td>
<td>1 250</td>
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<td>Rounding value (pcs)</td>
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<td>10</td>
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<td>8 288</td>
<td>4 070</td>
<td>1 242</td>
<td>351</td>
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<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td></td>
<td>Drawing revision</td>
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### Internal ability to produce

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<tr>
<th>Required resources</th>
<th>D26A, Tvätt, QC, Avsyn, Alkal, Avsyn, QC, Alkal, Mont, QC, QC, Lager</th>
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<tr>
<td>Number of operations</td>
<td>12 12 7 9</td>
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<td>Scheduled overlap</td>
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<td>Calculated quantity, EOQ (pcs)</td>
<td>8 750 4 000 800 300</td>
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<td>Changeover time</td>
<td>15h 15h 15h 8h</td>
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<td>Production lead-time</td>
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<tr>
<td>Mean manufacturing order (pcs)</td>
<td>7 716 4 070 1 242 468</td>
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<tr>
<td>Result from previous runs</td>
<td>98% 94% 102% 65%</td>
</tr>
</tbody>
</table>

### Actual flow of production

| Actual application of overlap | Yes 1 Yes 2 Yes 2 Yes 2 |
| Production flow               | Real overlap Operational overlap Operational overlap Operational overlap |
| Based on manufacturing order size | 9000, 9000 4100 1350 375 |

### Raw material

| Lead-time for raw material | Arrives prior to the customer order Arrives prior to the customer order Arrives prior to the customer order Arrives prior to the customer order |
### Appendix 9: Product classification, Company G

<table>
<thead>
<tr>
<th>Product specifications</th>
<th>Product G1</th>
<th>Product G2</th>
<th>Product G3</th>
<th>Product G4</th>
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<tbody>
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<td><strong>Product family</strong></td>
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<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td><strong>Margin</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Complexity</strong></td>
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<td>1</td>
<td>1</td>
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<tr>
<td><strong>Type of product</strong></td>
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<td>Intermediate product</td>
<td>Customer product</td>
<td>Intermediate product</td>
</tr>
<tr>
<td><strong>Purchased product</strong></td>
<td>Partly</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Promised lead-time</strong></td>
<td>N/A, according to throughput time or finished goods inventory</td>
<td>N/A, according to throughput time or finished goods inventory</td>
<td>N/A, according to throughput time or finished goods inventory</td>
<td>N/A, according to throughput time or finished goods inventory</td>
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<td><strong>State in life cycle</strong></td>
<td>Growth</td>
<td>Growth</td>
<td>Growth</td>
<td>Growth</td>
</tr>
<tr>
<td><strong>Yearly demand (pcs)</strong></td>
<td>2 363 000</td>
<td>2 605 890</td>
<td>518 480</td>
<td>5 733 170</td>
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<td><strong>Rounding value (pcs)</strong></td>
<td>1 000 000</td>
<td>1 000 000</td>
<td>1 000 000</td>
<td>0 000 000</td>
</tr>
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<td><strong>Mean customer order (pcs)</strong></td>
<td>40 034</td>
<td>127 107</td>
<td>40 196</td>
<td>145 148</td>
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<td><strong>Batch handling</strong></td>
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<td>No</td>
<td>No</td>
<td>No</td>
</tr>
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<td><strong>Drawing revision</strong></td>
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<td>2</td>
<td>2</td>
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<tr>
<td><strong>Number of operations</strong></td>
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<td>7</td>
<td>1</td>
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<td><strong>Scheduled overlap</strong></td>
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<td>Not scheduled</td>
<td>Not scheduled</td>
<td>Not scheduled</td>
</tr>
<tr>
<td><strong>Calculated quantity, EOQ (pcs)</strong></td>
<td>10 000</td>
<td>10 000</td>
<td>10 000</td>
<td>10 000</td>
</tr>
<tr>
<td><strong>Changeover time</strong></td>
<td>0h</td>
<td>8h</td>
<td>8h</td>
<td>0h</td>
</tr>
<tr>
<td><strong>Production lead-time</strong></td>
<td>16 days</td>
<td>129 days</td>
<td>164 days</td>
<td>1 day</td>
</tr>
<tr>
<td><strong>Mean manufacturing order (pcs)</strong></td>
<td>127 592</td>
<td>164 071</td>
<td>65 296</td>
<td>443 751</td>
</tr>
<tr>
<td><strong>Result from previous runs</strong></td>
<td>98%</td>
<td>99%</td>
<td>103%</td>
<td>N/A, purchased product</td>
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</table>

### Internal ability to produce

<table>
<thead>
<tr>
<th>Actual flow of production</th>
<th>Actual application of overlap</th>
<th>Production flow</th>
<th>Based on manufacturing order size</th>
<th>Raw material</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No</td>
<td>Straight flow</td>
<td>164000, 146000, 180000, 100000</td>
<td>196 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>100000, 100000, 100000, 213000</td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>100000, 148000, 75000</td>
<td>196 days</td>
</tr>
</tbody>
</table>

### Raw material

| Lead-time for raw material | 196 days | 196 days | 196 days | 196 days |
## Appendix 10: Product classification, Company H

<table>
<thead>
<tr>
<th>Product specifications</th>
<th>Product H1</th>
<th>Product H2</th>
<th>Product H3</th>
<th>Product H4</th>
</tr>
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<tbody>
<tr>
<td><strong>Product family</strong></td>
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<td>N/A</td>
<td>N/A</td>
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<td><strong>Margin</strong></td>
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<td></td>
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<tr>
<td><strong>Complexity</strong></td>
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<td>1</td>
<td>1</td>
<td>2</td>
</tr>
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<td><strong>Type of product</strong></td>
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<td>Intermediate product</td>
<td>Customer product</td>
<td>Intermediate product</td>
</tr>
<tr>
<td><strong>Purchased product</strong></td>
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<td>No</td>
<td>No</td>
<td>Partly</td>
</tr>
<tr>
<td><strong>Promised lead-time</strong></td>
<td>N/A, according to throughput time or finished goods inventory</td>
<td>N/A, according to throughput time or finished goods inventory</td>
<td>N/A, according to throughput time or finished goods inventory</td>
<td>N/A, according to throughput time or finished goods inventory</td>
</tr>
<tr>
<td><strong>State in life cycle</strong></td>
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<td>Maturity</td>
<td>Maturity</td>
<td>Maturity</td>
</tr>
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<td><strong>Yearly demand (pcs)</strong></td>
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<td>10,400</td>
<td>5,986,680</td>
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<td>100</td>
<td>1,000</td>
</tr>
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<td><strong>Mean customer order (pcs)</strong></td>
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<td>1,624</td>
<td>67,030</td>
</tr>
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<td>No</td>
<td>No</td>
</tr>
<tr>
<td><strong>Drawing revision</strong></td>
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<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td><strong>Required resources</strong></td>
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<td>Lego3, QC, Lager</td>
<td>Jenny, Tvätt, Pack, QC, Lager</td>
<td>Lego57, QC, Lager</td>
</tr>
<tr>
<td><strong>Number of operations</strong></td>
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<td>3</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td><strong>Scheduled overlap</strong></td>
<td>Not scheduled</td>
<td>Not scheduled</td>
<td>Not scheduled</td>
<td>Not scheduled</td>
</tr>
<tr>
<td><strong>Calculated quantity, EOQ (pcs)</strong></td>
<td>100,000</td>
<td>200,000</td>
<td>10,000</td>
<td>50,000</td>
</tr>
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<td><strong>Changeover time</strong></td>
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<td>8h</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Production lead-time</strong></td>
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<td>17 days</td>
<td>16 days</td>
</tr>
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<td><strong>Mean manufacturing order (pcs)</strong></td>
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<td>98%</td>
<td>75%</td>
<td>99%</td>
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</table>

### Internal ability to produce

| Actual application of overlap | No | No | No | No |

### Actual flow of production

| Based on manufacturing order size | 200000, 200000, 200000, 200000, 23900, 2180000, 2010000, 1900000 | 3600 | 222000, 205000 |

| Raw material | Lead-time for raw material | 196 days | 196 days | 196 days | 196 days |

### Raw material

| Lead-time for raw material | 196 days | 196 days | 196 days | 196 days |

### Production flow

- Straight flow
- Straight flow
- Straight flow
- Straight flow

### Based on manufacturing order size

- 200000, 200000, 200000, 200000, 23900, 2180000, 2010000, 1900000
- 3600
- 222000, 205000
## Appendix 11: Product classification calculations

<table>
<thead>
<tr>
<th>Product</th>
<th>Promised lead-time / production lead-time (EOQ)</th>
<th>Mean manufacturing order / mean customer order</th>
<th>Yearly demand / mean customer order</th>
<th>Yearly demand / EOQ</th>
<th>Yearly demand / mean manufacturing order</th>
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<td>10,80</td>
<td>1,49</td>
<td>1,44</td>
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<td>1,71</td>
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<td>1,33</td>
<td>1,32</td>
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<td>N/A</td>
<td>N/A</td>
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<td>49,64</td>
<td>3,57</td>
<td>9,03</td>
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<td>5,79</td>
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