Lead time analysis and reduction at Alfa Laval DC Lund

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Autumn 2012
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Preface

This master thesis was conducted at the Faculty of Engineering at Lund University during the fall of 2012. It is the last part of our master studies in Mechanical Engineering and Industrial Engineering and Management. The thesis was initiated to provide Alfa Laval DC Lund with a new view of their business and what areas of improvement that could be identified.

A great deal has been learnt during this master thesis in areas such as project managing, ERP systems, computer tools etc. It has been both a challenging and fun experience.

First of all we would like to thank our project group for their input on solutions and high quality information about the business. We would also like to thank the steering committee and other involved personnel at Alfa Laval DC Lund that have been helpful during the project.

We would also like to thank Bertil I Nilsson, our supervisor at Lund University, for guiding us and ensuring the quality of this thesis. Last but not least we want to give a big thank you to Joakim Svensson, our supervisor at Alfa Laval DC Lund, for the extensive amount of time and effort he has put into us and our project.

Lund 2013-01-30

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Abstract

Title Lead time analysis and reduction at Alfa Laval DC Lund

Keywords Lead time, ERP (Enterprise Resource Planning) system, Lean

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Background Alfa Laval DC Lund is both a spare part manufacturer and distributer. The spare parts that Alfa Laval DC Lund supplies are used for the heat transfer business unit of Alfa Laval. Sometimes orders need to be produced fast as customers may have breakdowns in production and sometime orders arrive months earlier than customers want to receive delivery as scheduled services occur at the customer.

Problem A problem today is that the time it takes Alfa Laval DC Lund to produce and send an order to a customer is perceived as too long. It is not known where in the process the majority of time is spent as well as what can be done to reduce it.

Purpose The purpose is to perform a thorough analysis of the lead time for manufacturing orders from that the customer order arrives at Alfa Laval DC Lund to the customers receive delivery.

Objective A solution that will reduce lead time for manufacturing orders should be created and implemented.

Deliverables The project should deliver savings/profit of 5000 euro per year and/or a process improvement of 25%.

Methodology The research has had a systems approach which was helpful to provide a holistic perspective. A combination of a case study and action research has been used to build a thorough understanding of the business before trying to improve it. Data has been gathered through interviews, observations, literature studies and from measuring processes and extracting data from the ERP system's database. During the research, emphasis has been on ensuring that reliable and valid data has been used.

Results

The production lead time data in Movex was adjusted to better fit the actual production lead time. The result was a decrease in lead time which could be seen directly after implementation.

Conclusion

The benefits of the implemented solution will be a 30% decrease in internal lead time when material is available from start and a 10% decrease in internal lead time when material is not available from start. This will in turn generate a total of approximately 14 000 euro per year in savings from less tied up capital and profits from earlier revenue. The analysis has also yielded information that Alfa Laval DC Lund can use to start new projects with the purpose to reduce lead time and/or improve their business.

It has been concluded that human interference with as well as wrong data in the ERP system drives lead times. The research also demonstrates the importance of working with the ERP system and using its features in a correct way instead of working beside and overriding it.

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Acronyms and glossary

A.s.a.p.	**As soon as possible.**
CO	A **Customer Order** contains all articles that customers have ordered as well as other information e.g. request date etc.
CRD	**Customer Request Date** is the date that the customer has requested delivery of the CO (or part of it).
DC	**Distribution Center.**
ERP system	A **Enterprise Resource Planning system** is a system that keeps track of all information needed in the business such as financial transactions, article database, customer information etc.
Minitab	Software for statistical analysis of datasets.
MO	A **Manufacturing Order** is an internal term used for articles that need to be produced or assembled.
Movex	ERP system used at all Alfa Laval's distribution centers.
OEE	**Overall Equipment Effectiveness** evaluates and indicates how effectively a manufacturing operation is utilized.
QlikView	Software used to illustrate and analyze data.
SI	A **Stocked Item** is a high runner item which is kept in stock (according to forecasted demand).
WIP	**Work In Progress** is products that are currently in the production process.

1 Introduction

In this chapter an introduction to the report will be made. The company background, problem formulation, purpose and delimitations will be presented which will clarify the outline of the project. A chapter overview will also be included to provide the reader with an overview of the report.

1.1 Company background

Alfa Laval was founded in 1883 by a man named Gustaf de Laval and his partner Oscar Lamm Jr. Since then the company has grown substantially and currently has 16 000 employees worldwide with the majority as well as the headquarters in Lund Sweden. Alfa Laval has customers in nearly 100 countries and they are in a wide range of industries. Alfa Laval is currently the world leader in heat transfer products but the company is also active in two other areas; separation and fluid handling (Alfa Laval, 2013a).

1.1.1 Business unit DC Lund

Alfa Laval DC Lund is both a spare part manufacturer and distributer. The DC was previously located at the headquarters in Lund but it was moved to Staffanstorp where it is currently positioned. The reason it was moved from Lund was that more space was required and the municipality would not give Alfa Laval building permit for the expansion needed. The spare parts that Alfa Laval DC Lund supplies are used for the heat transfer business unit of Alfa Laval.

The operations performed in Staffanstorp are mainly warehousing and a limited amount of production. It works as a distribution center in the traditional sense but products are also manufactured on the same site. The production department is the largest of all production departments at the distribution centers worldwide. In total there are approximately 45 employees at DC Lund.

Movex is used as ERP system in all distribution centers globally although all other facilities use Jeeves. All distribution centers were using Jeeves before as well but it was thought that Movex had better support for warehousing, which is the main function at the DCs, while Jeeves was thought to be better in handling production.

As the distribution center supplies spare parts, orders sometimes need to be produced fast as customers may have breakdowns in production. There has been at least one instance where plates have been transported by helicopter to oilrigs in

Norway for this reason. In contrast to this some orders arrive months earlier than customers want to receive delivery as scheduled services are also performed.

1.1.2 Products and articles

As mentioned Alfa Laval DC Lund's area of business are heat exchangers. To get an understanding of the products and articles they are handling a brief introduction will be made to Alfa Laval's heat exchanger components. The large majority of the articles handled are plates and gaskets but there are also other articles such as bolts, frames (the blue parts in Figure 1-2), pumps etc. The size of the plates varies from 10x35cm to 120x300cm which demands flexibility in both production and in the warehouse.

In Figure 1-1 a heat exchanger plate can be seen. This particular plate has a glue-less clip-on gasket which means that the gasket is held in place by the black clips that can be seen as black extensions of the gasket at the edges of the plate. The clip-on gaskets are easy and fast to mount. There is also another kind of gasket that is glued in place. The mounting of these gaskets are much more time consuming as glue has to be applied before the gasket can be mounted. After this the plate and gasket needs to go into an oven for several hours for the glue to harden. When the plates have cooled down the gaskets need to be inspected to ensure that the glue has cured and that the gasket is secured. These are the two methods used to mount gaskets on plates.

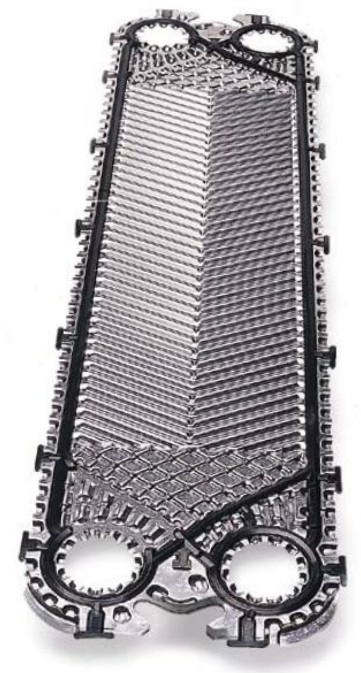

Figure 1-1: Heat exchanger plate with clip-on gasket (Alfa Laval, 2013b).

The customers are using these plates in their existing heat exchangers when something breaks, at a planned services or when they want to extend the plate package to increase performance of the heat exchanger. The heat exchanger itself can be seen in Figure 1-2. It works by running warm and cool liquid every other plate as seen in the figure. The plates are mounted on hangers and the heat exchanger is held together under a high pressure with large bolts (not shown in the figure).

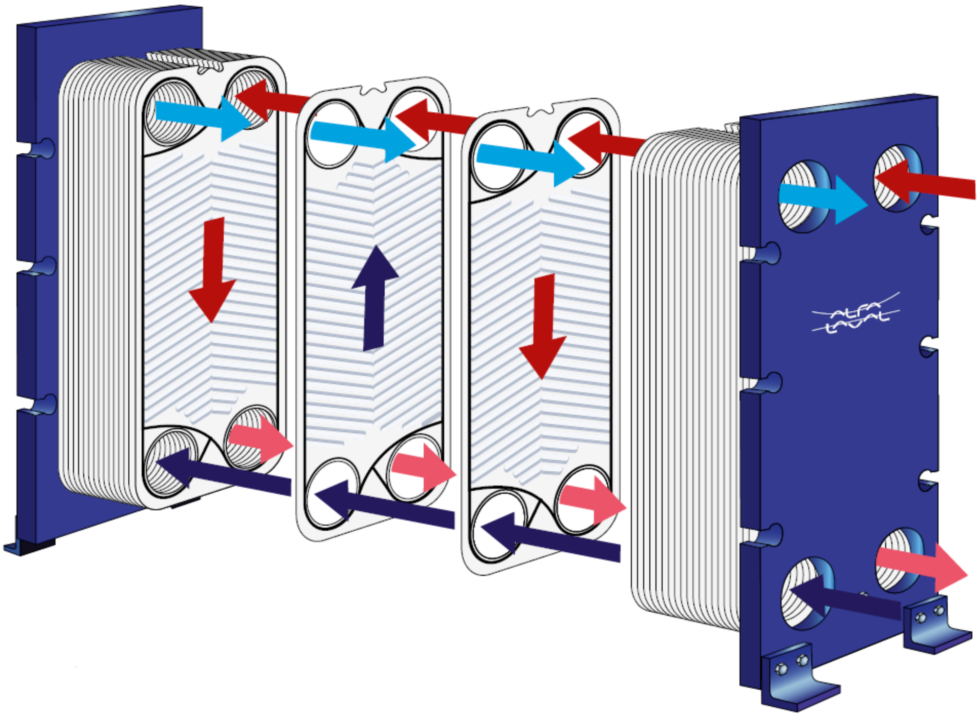

Figure 1-2: Functional overview of a heat exchanger (Alfa Laval, 2013b).

1.1.3 Order handling

The order handling process starts when Alfa Laval DC Lund receives an order from the end-customer directly or from a sales office. Orders can arrive electronically with EDI (Electronic Data Interchange) or by email, phone, fax etc. When orders arrive by EDI they are automatically entered into Movex but when they arrive in other ways the customer service department has to manually enter then into Movex. If an order that arrives only contains articles that are held in stock, the articles are picked, packed and the order is shipped. If the order contains products (that need to be manufactured) the order process is different as can be seen in Figure 1-3. The parallelograms in the figure represent a registered event in Movex.

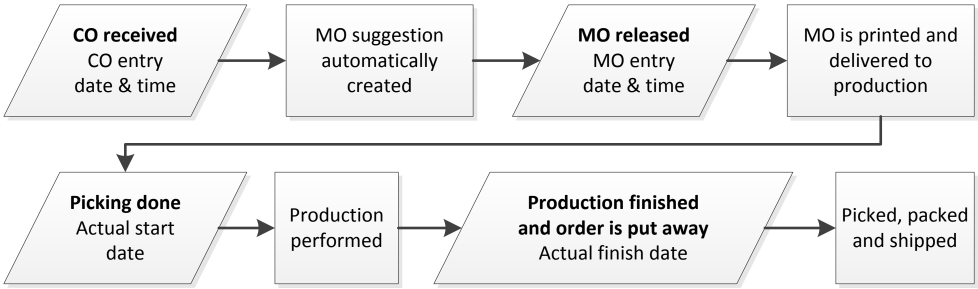

Figure 1-3: Manufacturing order process at Alfa Laval DC Lund.

All products and articles are forecasted and the products with high demand are manufactured to stock. This is used so that these products can be picked directly from the warehouse resulting in that customers will not have to wait for the production. For these products MO suggestions are created automatically when the inventory level drops to or below the safety stock.

1.1.4 Production

The production is divided into three work centers; C10, R10 and X10. These work centers are also present in Movex and contains different work operations in production. Different products require different work operations, meaning that all operations in a work center do not have to be performed.

The C10 work center handles punching of article numbers as well as the mounting of the clip-on gaskets to plates. If any other operations are needed the production is carried out in the X10 work center.

In the R10 work center roughening of gaskets is performed. This is performed more and more seldom as development of the products is progressing. Roughening is performed only so that the gaskets attach better to the plate when the gasket should be mounted using glue.

The X10 work center handles all other operations. This includes punching of holes and article numbers, projection welding of hanger reinforcements, spot welding of plate strengtheners (only used on older plates), applying glue, mounting gaskets, putting the plates in the oven as well as inspecting the gaskets after the oven.

The hanger reinforcements are projection welded to the end of the plate on each side. In Figure 1-1 it is in the same place as the indentation at each end of the plate, one should however note that this particular plate does not have extra hanger reinforcements welded to it.

1.2 Change of scope

1.2.1 Introduction

Initially the project had a scope with the purpose to "Increase the number of orders finished to customer request date by 25%". However this was not a suitable purpose so it had to be changed. The reasons for this will be presented in this chapter.

1.2.2 Data collection

To be able to make conclusions regarding the fulfillment of CRD, data had to be extracted from Movex. This data was then processed and analyzed in QlikView and Microsoft Excel. In the current system setup it is not possible, in a simple manner, to determine whether a customer request delivery as soon as possible or to a specific date that can be achieved with the current lead time. In order to determine this the production lead time, route departure days as well as transportation time has to be regarded. A function has therefore been created that takes all of these times into consideration and then determines if the CRD is achievable or not. If it is achievable it is regarded as realistic, while if it is not achievable it is regarded as the customer request delivery as soon as possible (a.s.a.p.).

1.2.3 Empirics and analysis

The result of the data collection was conclusive. On average the amount of MOs where the customer has requested delivery a.s.a.p. is 85%. This means that on average only 15% of customers request delivery at a date that is achievable. The variation of realistic CRD over time can be seen in Figure 1-4.

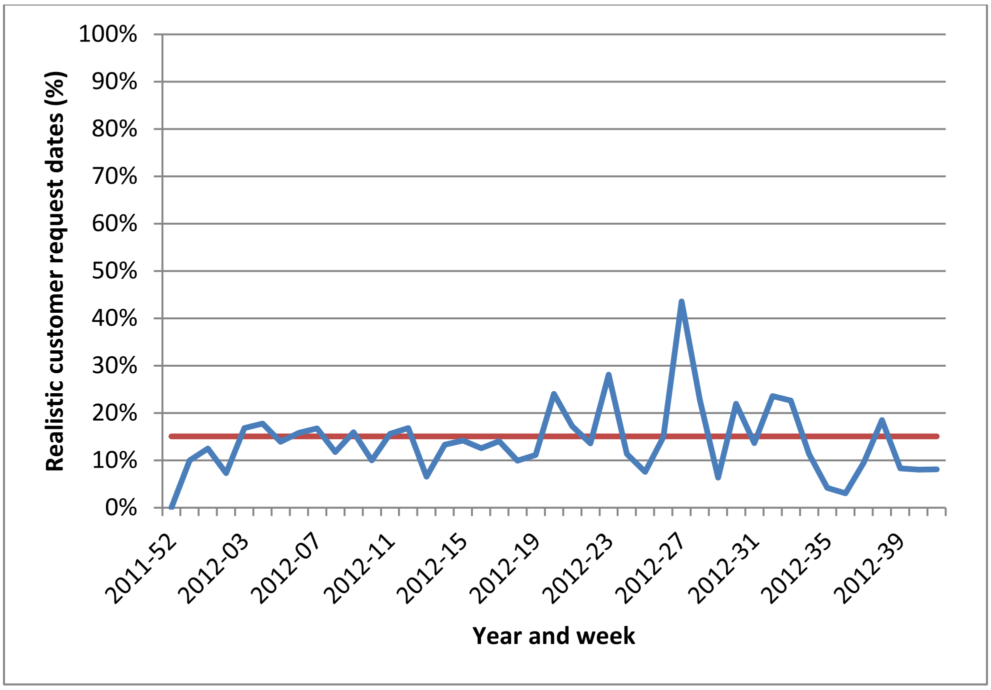

Figure 1-4: Average amount of MOs with realistic CRD per week.

As can be seen in Figure 1-5, CRD is met for 12,4% of all MOs. In comparison to that 15% of all MOs have a realistic CRD this means that only 2,6% of all MOs could be improved.

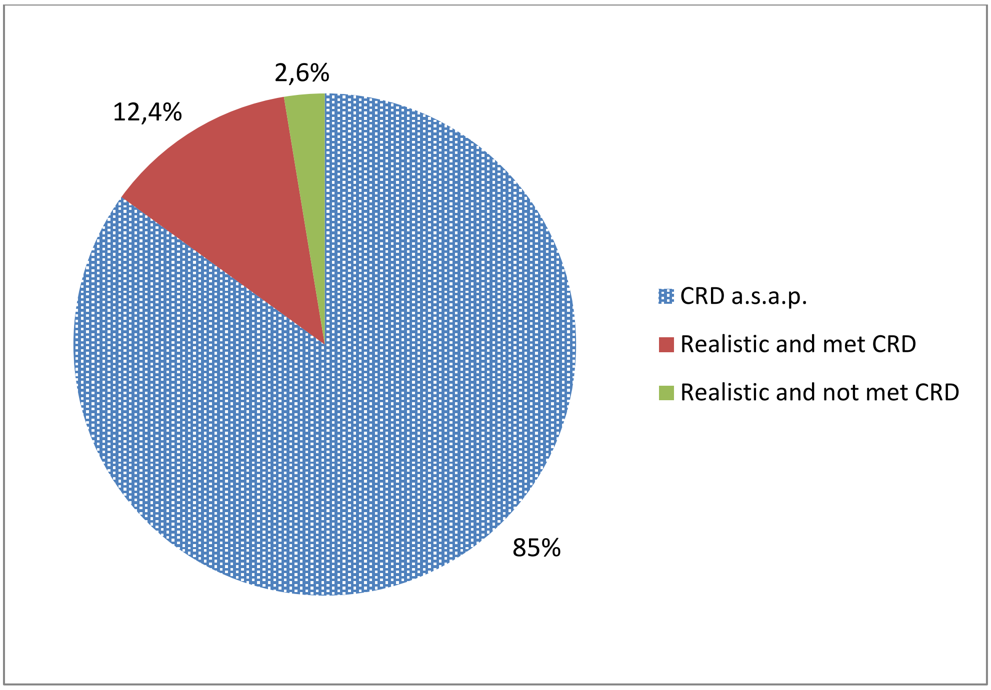

Figure 1-5: Overview of CRD status for all MOs.

1.2.4 Conclusions

As mentioned only 2,6% of all MOs on average could be improved within this initial scope of work. It is not economically justifiable to improve such a small amount of the population. A project of this size should have a more ambitious purpose.

Alfa Laval DC Lund's intentions were to increase customer service and cater to the customers' needs in a better way. Another scope that would achieve this was therefore desirable. As customers request delivery as soon as possible in 85% of all MOs on average a lead time reduction would therefore be appropriate to increase customer service. The origin of lead time is currently not known. After consulting with management it was decided that an analysis of where the lead time originates from should be made as well as a lead time reduction, if possible within the delimitations of the project.

1.3 Problem description

A problem today is that the time it takes for Alfa Laval DC Lund to produce and send an order to a customer is perceived as too long. It is not known where in the process that the majority of time is spent as well as what can be done to reduce it.

After the initial change of scope it was concluded that on average 2012, 85% of customers request delivery as soon as possible. This is understandable as Alfa Laval DC Lund supplies spare parts. The customer needs could therefore potentially be catered to in a better way if the lead time was decreased. However, to be able to decrease the lead time it is important to obtain an understanding of where in the process the majority of time lies.

1.4 Purpose

The purpose is to perform a thorough analysis of the lead time for manufacturing orders from that the customer order arrives at Alfa Laval DC Lund to the customers theoretically receive delivery (based on predefined transportation/shipment time). The analysis should yield an overview of the lead time and pinpoint areas of improvement potential.

1.5 Objective

A solution that will reduce lead time for manufacturing orders should be created and implemented. After the implementation of this solution further research areas should be identified and presented.

1.6 Deliverables

The project should deliver at least one of the following:

- Savings/profit of 5000 euro per year
- Process improvement of 25%

1.7 Delimitations

To prevent the project from becoming too complex the following delimitations has been made:

- The project should focus on manufacturing orders connected with a customer order.
- No changes will be made to suppliers or the purchasing department.
- Customer behavior should not be changed.
- No changes should be made to the sales department.
- When measuring the lead time the transportation time will not be measured in reality, the time it takes according to Movex data will be used instead.
- No analysis or modification will be made to physical material handling in the warehouse.

- Only internal processes in Alfa Laval DC Lund will be analyzed and changed.
- The analysis will be limited to orders placed at Alfa Laval DC Lund.

1.8 Chapter overview

1 Introduction
In this chapter an introduction of the report has been made. The company background, problem formulation, purpose and delimitations have been presented to clarify the outline of the project.

2 Methodology
This chapter will present the research methodology used throughout the project.

3 Theory
The theoretical framework that has been used will be presented in this chapter.

4 Data collection
In this chapter the data that will be collected is going to be described. Why and how the data will be collected will also be described.

5 Empirics and analysis
The data described in chapter 4 Data collection will be presented and analyzed in this chapter. Areas with improvement potential will be distinguished and analyzed further.

6 Improvement proposals
This chapter will include concrete suggestions of improvements that will be made based on the analysis.

7 Implementation
Chosen implementations as well as how to implement and evaluate them will be presented here.

8 Results
In this chapter the results after the implementation will be presented.

9 Conclusions and discussion
Conclusions from the research will be drawn as well as recommendations for further research. Scientific contributions of the research will also be presented.

2 Methodology

This chapter will present the research methodology used throughout the project.

2.1 Approach

Arbnor and Bjerke (2009) defines that there are three types of methodology approaches to research, depending on what the research question is as well as what view the researcher has on reality. They also argue that the view of reality in fact determines how the question is asked and thus how the problem could be solved. The three approaches are the analytical approach, the systems approach and the actors approach. Each one of the approaches will be described in this chapter.

Combining the different approaches will not result in a better approach. Arbnor and Bjerke (2009) do however state that it is possible to use one as a base approach and then add complimentary methodical procedures from one of the other approaches. It is although important to be extra careful when this type of complementing is used.

2.1.1 Analytical approach

The perception of reality in the analytical approach is that the “whole” is equal to the sum of its components. This means that when using an analytical approach, it is possible to explain a phenomenon by examining each individual component. The perception is also that any knowledge obtained or created with an analytical approach is independent of the observer (Arbnor & Bjerke, 2009).

As any knowledge obtained is independent of the observer, literate studies are commonly used to a large extent when gathering data in the analytical approach. Gathering data through interviews, surveys, observations and experiments is also common. The data is then analyzed using statistical tools and the objective is to achieve a high level of generalization. A high emphasize on disclosing how and where data were collected, which definitions that were made, etc. is common for this approach (Arbnor & Bjerke, 2009).

2.1.2 Systems approach

In the systems approach, contrary to the analytical approach, the perception of reality is that the “whole” is not equal to the sum of the components. This means that the components themselves cannot be studied individually, as their relations also affect the phenomenon. This means that the whole system needs to be studied to be able to explain or understand a phenomenon (Arbnor & Bjerke, 2009).

Studies performed with a systems approach often gather information from observations and interviews as case studies are a preferred research method. Since real life systems are often quite different from each other, secondary information as gathered using literature studies from another system are handled with care, as the result might not be transferable. Although secondary information within the system being studied is extensively used. Because results are difficult to transfer to other studies, systems approached projects do not strive for a high level of generalization (Arbnor & Bjerke, 2009).

2.1.3 Actors approach

In the actors approach reality is perceived as socially constructed and that humans create reality at the same time as reality creates us. Knowledge is therefore also perceived as socially constructed, meaning that the creation of knowledge depends on the involved individuals as well as the researcher's own interpretations. To understand a phenomenon, the whole social construction needs to be understood (Arbnor & Bjerke, 2009).

With the actors approach it is most common to gather information through personal interviews or dialogs with the involved individuals. Participative observations are also used to create an understanding. Literature studies are only performed on information that is closely related to the same social construction. And as with the systems approach projects do not strive for a high level of generalization (Arbnor & Bjerke, 2009).

2.1.4 Summary

Gammelgaard's (2004) summary of Arbnor and Bjerke's three types of approaches can be seen in Table 2-1.

Table 2-1: Gammelgaard's (2004) summary of Arbnor and Bjerke's three types of approaches.

	Analytical approach	Systems approach	Actors approach
Theory type	Determining cause-effect relations. Explanations, predictions. Universal, time and value free laws	Models. Recommendations, normative aspects. Knowledge about concrete systems	Interpretations, understanding. Contextual knowledge
Preferred method	Quantitative (qualitative research only for validation)	Case studies (qualitative and quantitative)	Qualitative
Unit of analysis	Concepts and their relations	Systems: links, feedback mechanisms and boundaries	People – and their interaction
Data analysis	Description, hypothesis testing	Mapping, modelling	Interpretation
Position of the researcher	Outside	Preferably outside	Inside – as part of the process

2.2 Research method

There are a number of methods on how to perform research. Höst et al. (2006) state that the four most relevant methods, when conducting applied science, are:

- Survey
- Case study
- Experiment
- Action research

2.2.1 Survey

Using surveys as a research method is most suitable when the purpose of a project is to describe and or predict how a process or a phenomenon works. Using surveys means that information is gathered from a sample of people from the population, where the result can be applied to the whole population. The information can either be gathered by asking questions directly, by phone or face-to-face, or by sending written questions, by mail or email, to the respondent (Sellstedt, 2002). The advantages of asking questions directly to the respondent are that it is possible to acquire clarifications on answers as well as that the responder is less keen to finish the survey prematurely. The disadvantage however is that it is time consuming. The main advantage with sending written questions is that a larger sample from the population can be targeted. The disadvantage is that it is harder to obtain sufficient precision and depth (Höst, et al., 2006).

2.2.2 Case study

Case studies are suitable when the purpose of a project is to obtain a deeper understanding and description of an object or phenomenon (Höst, et al., 2006).

Case studies can also be used when the aim of a project is to reveal areas in need of further research (Gimenez, 2005). Näslund (2002) states that case studies are appropriate when answering “why” and “how” questions.

As case studies are performed at specific cases with specific objectives, the result of the study will most likely not be generalizable. However, for another case with similar conditions the probability of obtaining the same result is large. When performing case studies it is common to use interviews, observations as well as literature studies (Höst, et al., 2006). With these tools a greater knowledge can be obtained then that would be possible from purely using statistical analysis of preformatted questionnaires (Gimenez, 2005).

2.2.3 Experiment

Experiments are a well suited research method when the aim of a project is explanatory, to find causation and explanations of phenomena. Experiment research is as the name implies studies performed by experimenting with parameters and examining their impact on the phenomenon (Höst, et al., 2006). The strength of using experiments is the control the practitioner can have over the different parameters. An issue that can arise when using experiment research is however to what extent the result is applicable to real life situations (Sellstedt, 2002).

2.2.4 Action research

When the purpose of a project is to improve something while studying it, action research is well suited. Performing action research is an iterative process; the situation or phenomenon is observed to enlighten which problems that should be solved, solutions are developed and implemented and the solution is then evaluated. The process should then be iterated until the situation or phenomenon is functioning satisfactory (Höst, et al., 2006). Collaboration between the researcher and members of the studied system is an important characteristic of action research as the research should be interactive (Müller, 2005).

Näslund (2002) states that action research is an appropriate method when handling real world problems encountered in supply chain management.

A potential problem with action research is the high extent that the researcher is involved in the process and thus becoming impartial (Bichou & Gray, 2005). This can however be countered by setting up clear criteria for the evaluation. External controllers can also be used to ensure a valid and reliable result (Höst, et al., 2006).

2.3 Gathering data

Gathered data can be either quantitative or qualitative, which type that should be gathered depends on the specific situation. By which technique the data should be gathered also depends on the situation, as will be presented below.

2.3.1 Quantitative vs. qualitative data

Quantitative data consists of data that can be measured and classified, such as amounts, proportions, times, etc. Quantitative data can be processed using statistical analysis, for example by using boxplots and or histograms. When analyzing quantitative data it is very important to investigate if the data contains incorrect values, so that these do not mislead the result. Qualitative data on the other hand consists of descriptions rich in detail that cannot be simply measured. Analysis of qualitative data should be based on encoding, sorting and categorizing the gathered data (Höst, et al., 2006).

Höst et al. (2006) state that gathering a combination of qualitative and quantitative data is appropriate for problems which involve humans and their actions.

2.3.2 Techniques

In this chapter information on gathering data by using interviews, observations, literature studies and measurements will be presented.

Interviews

Interviews are a way of systematically questioning relevant personnel on a particular subject. Interviews are often divided into three different types; structured, semi-structured and unstructured. The type of interview that should be used depends on the purpose. Structured interviews consist of predefined questions that are asked in a specific order and are used when the purpose of the interview is to describe the phenomenon. Semi-structured interviews consist of some predefined questions as well as some open questions. Semi-structured interviews are useful when the purpose is more explanatory. Unstructured interviews consist of some questions to support and help the interviewer to manage the interview, but are to a large extent open for the interviewee to control. Unstructured interviews are convenient to use when the purpose of the interview is to get an exploratory understanding (Höst, et al., 2006).

Observations

An observation means that an event is studied and the findings are noted. The observer can either be participating in the studied event or not. Participation creates a greater knowledge and trust for what is being observed, there is however a risk of losing the objectiveness. The opposite applies to observers that do not participate, they have a objectiveness but may not fully understand the observed event. Observers also have the option whether or not to tell the observed personnel that they are being observed. If the observer is exposed there is a risk that this will affect the observed phenomenon. Personnel may work different if they know that they are being observed then they normally do. Having the personnel unaware of that they are being observed may on the other hand raise ethical issues (Höst, et al., 2006).

Literature study

To be able to ensure that the project has a stable scientific base, a literature study should be made. A literature study will also assist the researcher as there is no need to start completely from scratch and thus avoiding mistakes that others have encountered in previous research. It is also important to perform a literature study to understand the subject in question before tackling it head on in real life (Höst, et al., 2006).

The intention of making a literature study is thus to determine how far existing research has come, to avoid repetition and to bring science forward.

Measurements

Performing a measurement means that a number or a term is associated to attributes which describe a phenomenon. A measurement can be either direct or indirect. Direct measurements means that the value that is being measured can be read instantaneous, for example measuring the length of something. Indirect measurement is measurements where more than one attribute is measured and then combined, for example to measure speed both the traveled distance as well as the time it took is required (Höst, et al., 2006).

When measurements are performed by more than one person or at more than one occasion, it is very important that the measurement is thoroughly defined. If the definition is vague there is a risk of incoherent results. The time it takes to perform something can for example be measured in a number of different ways leading to completely different results (Höst, et al., 2006).

When analyzing the result of a measurement it is important to understand the potential errors that may exist in the data. The data can contain large errors (such as typing or reading errors), systematic errors (reoccurring errors that could be caused by interference to the measurement instruments) as well as temporary errors (random variations in the proximity of the actual value) (Höst, et al., 2006).

2.4 Credibility

It is important that drawn conclusions from research are well substantiated and that the right phenomenon has been studied. It is also preferred that the results are generalizable. This chapter will therefore further describe reliability, validity and representativeness.

2.4.1 Reliability

The reliability of gathered data and analyses are of great significance when performing research. It is important to be thorough when gathering data as well as when performing analyses. One way of ensuring that reliable data is being used is to involve and obtain coworkers opinions. Results or observations from interviews can also be discussed with the interviewed party to ensure that he or she has not been misinterpreted (Höst, et al., 2006).

2.4.2 Validity

It is important that the correct phenomenon is being measured to ensure validity. There need to be a connection between what is supposed to be measured and what actually is being measured. A method called triangulation can be used to get a clearer perception of the phenomenon. Triangulation means that data should by gathering by using different methods and thus seeing the phenomenon from different angles. When performing research during a long time period there is a risk of neglecting daily problem areas which in turn may threaten the validity. In these cases a third-party reviewer can be helpful to reduce this risk (Höst, et al., 2006).

2.4.3 Representativeness

Having generalizable results from research would be ideal. Researchers should thus aim for obtaining results that have a high representativeness. For surveys and experiments it is therefore important not to have a too high loss in data, or that losses are especially high in a specific category of the population. Case studies and action research will most probably not be generalizable, but the result can fit a similar case very well. It is therefore important to provide a thorough and detailed description of the studied case to increase the representativeness (Höst, et al., 2006).

2.5 DMAIC method

The DMAIC method can be described as a structured approach for solving problems (de Mast & Lokkerbol, 2012) (George, et al., 2004). The name DMAIC is taken from the first letter in each step in the methodology; Define, Measure, Analyze, Improve and Control. The methodology originates from Six Sigma and is according to George et al. (2004) widely used in businesses. de Mast & Lokkerbol (2012) states that DMAIC is suitable for extensive and complex projects while it is less suitable for projects with a smaller scope. The five steps in DMAIC will now be briefly described:

Define

The major parts in the define step is to define the projects purpose, objectives, delimitations and deliverables (George, et al., 2004).

Measure

A thorough understanding of how the processes work should be achieved in the measure step so that potential causes can be identified. A measurement plan should then be developed and data should be collected on the current processes (George, et al., 2004).

Analyze

After the data have been collected it should be analyzed to verify that the causes found in the previous step actually affect the process. This step is also known as “Finding the critical X’s” (George, et al., 2004).

Improve

In the improve step potential solutions to the problem should be developed and optimized. The best solution should then be implemented (George, et al., 2004).

Control

The control step has the purpose of verifying that the implemented solution is satisfactory as well as that the improvement is sustained (George, et al., 2004).

2.6 Chosen methodology

Throughout this project the DMAIC method will be used. The methodological approach in this report will be a systems approach, where the “whole” is not equal to the sum of its components, as their relations are of importance as well. The systems approach will help to provide a holistic view during the project. A combination of case study and action research will be used as the research method.

Initially the research will start off with a case study to build a thorough understanding of the business and processes. After this has been achieved the focus will be altered to improving the process while observing it. This means that the research method will be changed into action research.

Qualitative data in form of interviews with involved personnel, observations and a literature study will be gathered in combination with quantitative data in form of measuring processes and extracting data from the ERP system's (Movex) database. The interviews that will be conducted will be semi-structured to obtain an explanation and understanding of the process. Observations will be non-participating in nature and all observed parties will be informed before the observation. All data that will be collected through measurements will be verified by coworkers as well as by the supervisor at Alfa Laval DC Lund to ensure reliability. Data collected during both interviews and observations will be discussed and confirmed with relevant personnel for the same reason. To ensure validity, different methods of gathering data will be used in order to observe the phenomenon from different angles. The supervisor from Lund University will also review the research for ensuring validity. As the research will be carried out using both the case study as well as the action research method, it will not possible to obtain a generalizable result. The case will therefore be thoroughly described so that it hopefully can be applied to a similar situation.

3 Theory

In this chapter the theoretical framework that has been used will be presented.

3.1 Lean

As Alfa Laval is a company that tries to apply lean thinking to its business it is important to be familiar with the lean terminology and the way of thinking.

Lean has its roots in the car manufacturer Toyota and the Toyota Production System (TPS). In the 1980's it was discovered that Toyota was a high performing company in many ways. Toyota was producing cars of high quality at a competitive cost. The company was more profitable than its competition and removed their weaknesses effectively. The development of the cars was also fast. The success Toyota had and still has have been built on an excellent company culture that has become known as lean. There are several tools that facilitate the implementation of lean, some of which will be presented below, but this is just the tip of the iceberg (Liker, 2004). According to Liker (2004) lean is a company culture more than tools that are applied. Lean manufacturing can be seen as a five step process; defining customer value, defining the value stream, making it "flow", "pulling" from the customer and back and striving for excellence. This in combination with a culture in which everyone is striving for continuous improvements are considered to be lean (Liker, 2004).

Wang (2011) views lean more as a waste reduction philosophy that should use less human effort, manufacturing space, investment in tools, and engineering time to develop a new product. Some literature are focusing on that lean is the reduction of waste for example Wang (2011). This is a part of lean but this is however not a new concept. Henry Ford was for example an aggressive champion for waste reduction (Hopp & Spearman, 2004). Hopp & Spearman (2004) define lean in terms of factory physics as "*Production of goods or services is lean if it is accomplished with minimal buffering costs.*".

It is evident that the view of lean is different from author to author but these definitions provide an understanding of what lean is.

3.1.1 5S

The purpose with 5S is to improve the workplace organization and standardization (Wang, 2011). It is used to maintain an organized, clean, safe and high performing workplace (George, et al., 2004). It can and should be applied both in the office and in production (Bicheno, 2004). The idea is that if everything is in order abnormal behavior can be spotted faster (George, et al., 2004). An example of this could be car production, if the shop floor is clean a car that is leaking oil will be spotted faster than if the floor was dirty. The 5S are Sort, Set in order, Shine, Standardize and Sustain and are defined as the following (Bicheno, 2004) (George, et al., 2004) (Wang, 2011):

- **Sort:** All items that are not used should be removed.
- **Set in order:** Arrange and organize tools, materials etc. so that it is placed where it is needed and in a specific place.
- **Shine:** Make sure that the work space is clean.
- **Standardize:** Create a consistent way of performing operations.
- **Sustain:** Make sure that 5S is sustained.

3.1.2 JIT

JIT stands for Just In Time and is a large part of lean. The thought with JIT is that everything should arrive where it should at the right time, not earlier, not later. It would for example be better if suppliers deliver products directly when they are needed. This would in turn render inventory useless which is desirable. JIT is as lean not a tool itself but a philosophy how the business should be conducted (Hopp & Spearman, 2004).

3.1.3 Kanban

Kanban is a tool that facilitates the implementation of JIT. The idea is when something is demanded a kanban card is sent downstream in the production "pulling" the item precisely when it is needed. Pull ultimately represents the demand from the customer, a product is not produced before a customer demands it. There are several benefits with pull, for instance (Hopp & Spearman, 2004):

- Reduced Work In Progress (WIP) and cycle time
  - As products cannot enter production before they are needed the WIP will decrease. Kanban effectively creates a WIP cap.
- Smoother production flow
  - Variability in WIP will decrease and this in turn reduces variability in output.
- Improved quality
  - The pressure to improve quality increases as the quality of both products and processes become more important because defects will impact the production more.
- Reduced cost
  - The tied up capital in WIP is reduced for example.

3.1.4 7 wastes

The reduction of waste is a central part of lean. Toyota has identified seven major types of non-value adding activities, waste, in business. They are as follows (Liker, 2004):

- Overproduction
  - Production of items for which there are no orders.
- Waiting
  - Workers waiting for a process, waiting for inventory to become available etc.
- Unnecessary transport or conveyance
  - The moving of inventory or WIP.
- Overprocessing or incorrect processing
  - Could be unneeded process steps or when higher quality then needed is created.
- Excess inventory
  - Excess of raw material or WIP.
- Unnecessary movement
  - Workers should have to move as little as possible to reach tools, parts, material etc.
- Defects
  - Production of parts that have defects that in turn needs to be repaired, scrapped etc.

There is also an eighth waste that is unused employee creativity. Many ideas for improvement can come from employees and it is a waste not to engage or listen to them and take advantage of their input (Liker, 2004).

3.2 Six Sigma

Six Sigma has focus on two main areas; quality assurance and benchmarking. It has traditionally had a strong emphasis on statistical methods (Truscott, 2003) (de Mast & Lokkerbol, 2012). It focuses on continuous improvement of processes regarding both efficiency and effectiveness. Six Sigma aims at providing a universal measure of process performance where a higher sigma indicates a better result. Sigma represents the standard deviation of a normally distributed distribution. A one sigma process indicates that the process is successful in 30,85% of all cases (if it is normally distributed). A six (6) sigma process represents a process that succeeds in 99,99966% of all cases which in turn represent 3,4 defects per million opportunities (DPMO). Six sigma is considered to be a world class process although most companies are thought to operate around 2-4 sigma (69,146-99,379%) (Truscott, 2003).

3.3 Tools

In this chapter the theory behind the tools that will be used is going to be presented. These tools have been chosen to step by step identify and solve problem areas as they are proven to be effective for this (Lambert, 2008) (Oakland, 2004) (George, et al., 2004).

3.3.1 Process mapping

Process mapping and analysis is a powerful tool in helping companies become more competitive (Baker & Maddux, 2005). Process mapping could also help companies to develop their strategies (Gardner & Cooper, 2003). However one critical success factor of process mapping is important to remember. This is that cross-functional process mapping should be performed. The reason that cross-functional process mapping is so important is that processes could be sub optimized otherwise. Cross-functional process mapping will facilitate companies in seeing the broader perspective of its processes (Lambert, 2008).

Lambert (2008) presents one example to demonstrate the importance of cross-functional process mapping is a manufacturer of consumer goods in USA. This manufacturer implemented a system that would reduce their lead time to retailers to between 24 and 48 hours anywhere in the United States. This would in turn mean that the retailers could hold less inventory reducing the tied up capital and therefore increasing the profitability of the products, making them more attractive. However after a few years the manufacturer had not seen the decrease in retailer's inventory. The reason that this had not been seen was because the sales department had incentives in place that promoted purchasing of large volumes. This example highlights the importance of cross-functional process mapping as this could have been avoided if the business would have its processes aligned (Lambert, 2008).

3.3.2 Cause and effect analysis

When problems occur it is desirable to determine what has caused the problem. A useful tool when determining what has impact on a specific problem is a cause and effect analysis. To perform a cause and effect analysis a so called Ishikawa Cause and Effect (CE) Diagram or Fishbone diagram, as it is also called, can be used (Oakland, 2004) (Bilsel & Lin, 2012). An example of this diagram can be seen in Figure 3-1.

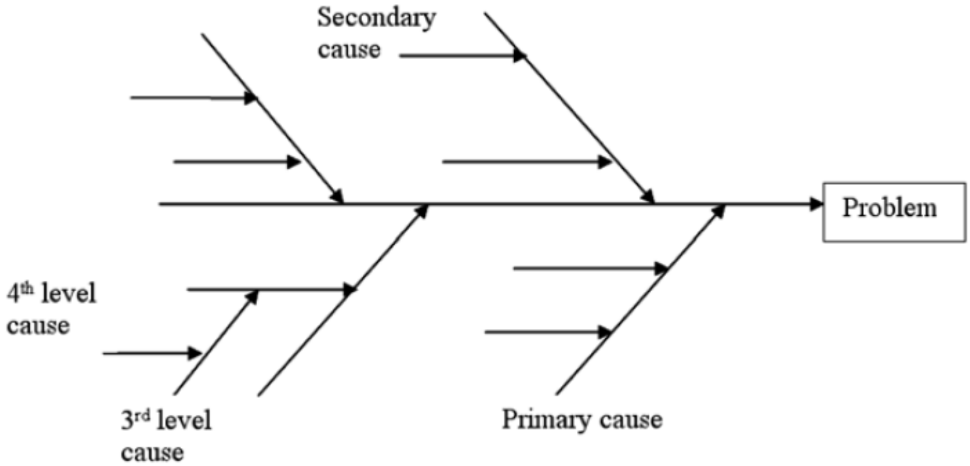

Figure 3-1: Cause and Effect diagram (Bilsel & Lin, 2012).

Potential causes should be found by brainstorming (Oakland, 2004) (Bilsel & Lin, 2012). The primary causes should be connected to the "bone" in the center. Each primary cause then has secondary causes which in turn have more causes connected. The root cause can be found this way (Bilsel & Lin, 2012) or root cause analysis could be performed on for example the secondary causes (George, et al., 2004).

3.3.3 Root cause analysis

Root cause analysis can be used to get to the bottom of a problem, i.e. find the root cause of the problem. There is a simple yet effective method to do this called 5 Why. The method is simply to ask the question why until the root cause is found (George, et al., 2004) (Bicheno, 2004). It could be both more or fewer than five times but in Toyotas experience, who is the inventor of 5 Why, five times is often the amount of times the question has to asked to find the root cause. This is thought to be one of the reasons that Toyota has an edge on quality, reliability and productivity. When they encounter a problem the do not only solve the obvious problem, they find the root cause to why it arose in the first place and change it (Bicheno, 2004).

3.4 Change management

When changes are imminent resistance to change should be expected as it in most cases occurs. Management should be prepared to handle this by having an understanding of the change that is going to happen and be prepared to answer questions and reassure the personnel that the change will work. Change should not be forced, if staff thinks the change is exciting it will be much easier to perform.

The staff could even help the change by making improvement suggestions and sharing their knowledge (Oakland, 2004).

There are six important activities when implementing change and they are (Merrell, 2012):

- Leading
- Communicating
- Learning
- Measuring
- Involving
- Sustaining

It is important that management has a strategy regarding change as well as support from top management. Good communication is also important to ensure that there is an understanding of the imminent change and what is about to happen. A fundamental step is that the employees learn how to perform their new tasks. This could yield feedback on the implementation suggestion pushing it in the right direction. To make sure that the change has worked as intended, clear measurements should be introduced. This is also useful after the change to make sure that the process that has been changed does not fall back to the way it was before. It is important that the measurements start before the change so a base line can be established. To reduce or avoid resistance to change completely, the staff/customers or others affected by the change should be involved. Last but not least it is important to make sure that the change is sustained. This can be done by making sure that the process does not go back to the way it was before. To indicate if this is happening measurements of the changing process could for example be used as mentioned before (Merrell, 2012).

4 Data collection

In this chapter the data that will be collected is going to be described. Why and how the data will be collected will also be described.

4.1 Introduction

To be able to identify what data that need to be collected a cause and effect analysis of why the lead time is long has been performed. The causes that were identified were then analyzed further using the 5 why method to find the root causes. The identified root causes were in turn examined to be able to determine which data that are needed in order to analyze what drives the lead time. A measurement plan was then created to get an overview of all measurements that are going to be performed.

To be able to get an understanding of the business that Alfa Laval DC Lund conducts, a series of interviews and observations have been performed apart from the data collection. In excess of 30 interviews have been carried out with employees, ranging from department managers to production staff, from all departments on site. Observations have mainly been focused on the planning process and the production but also customer service to some extent.

4.2 Measurements/Data collected

The measurements that will be performed as well as why and how they should be performed will be specified further in this chapter. To be able to ensure consistency throughout all measurements clear instructions on how to measure have been created. All data collected from Movex will also be thoroughly examined and validated for this reason.

4.2.1 Planning efficiency

One potential root cause identified to why the lead times are long was that the production planning could be inefficient. To get a better insight into the planning process several measurements will be performed:

- Data will be collected on how much time that is spent on production planning. This will be measured by letting the production planners register the time they are absent from the planning for other tasks.
- The amount of time that the planners spend on delivering papers to production will also be measured. This will be measured by letting the planners register when they leave to deliver papers to production as well as

when they return. By measuring this, an estimation of the actual time required to perform production planning can be made.

- The amount of papers that is printed by the production planners and then delivered and used in production will be estimated by calculating the average amount of papers used per MO for a large number of MOs and then multiplying this with the amount of MOs produced during 2012. This will be measured to get an overview of potential waste connected to production planning.
- To be able to evaluate how effective the production planning is the amount of times that production have finish a MO after the planned finish date will be collected. This will be done by extracting data from Movex on planned and actual finish dates and comparing these using QlikView and Minitab.

4.2.2 Capacity

Another potential root cause to long lead times that was found was that the capacity in production was constrained. It is however only possible to calculate the capacity utilization as well as the overall equipment effectiveness (OEE) in production on live data. To get an appreciation of OEE and how the capacity has been utilized in the past, overtime worked in production as well as the amount of temporary staff that has been used will therefore be collected.

The amount of worked overtime will be collected from human resources for the personnel that work in production. The amount of temporary staff used will be collected from the work schedule.

To calculate the OEE and capacity utilization in production data will be collected on how many hours that are put into production as well as how many hours that are performed in production, according to Movex. The data for the amount of hours that are put into production will be collected from the work schedule while the data on how much that is been performed in production will be collected from the database. The result of the calculated utilization is also in a way a measurement of how well the data in Movex correlates to the actual process.

4.2.3 Scrapped material

Scrapping of material in production was identified as a potential root cause to long lead times. If material is damaged in connection to production there is a potential risk of delaying MOs, which increases the time it takes customers to receive delivery. Data will therefore be collected from the database on how often scraping is made in the warehouse.

4.2.4 Lead time

In order to better understand what and where the lead time originates, the lead time has to be divided into smaller steps. The lead time data will be extracted from Movex database so historical data can be analyzed. When handling and analyzing the lead time it is important to know if a customer requests delivery on a specific achievable date or as soon as possible. It is also important to be able to determine when material was available for a MO on a CO to be able to assess whether potential waiting time was because of suppliers or not.

Date of available material

The current system setup does not keep record of when material became available for a MO or CO. The date and time of when material was available for a MO or CO therefore needs to be calculated using the stock transaction history in comparison with the demand history for MOs and COs.

Data will therefore be extracted for all components included in all products for all MOs and COs, these will then be consolidated to create a demand history. After that an allocation table with priorities should be created in the stock transaction history for all components in the demand history. It should be created in a way so that at the time when a CO was created or a MO released to production an allocation is noted and the quantity ordered is subtracted from the available stock on hand. MOs or COs that arrive later will receive a lower priority for its allocation. When material is picked the connected MO or CO is removed from the allocation table.

The date and time of available material for all components on a MO, as well as all articles on a CO, can then be determined by finding the correct component in the stock transaction history and examining the available stock on hand and the allocation table. If there is enough available stock on hand at the time and date of CO or MO entry to cover the ordered quantity, this date is set as the material available date. If there is not enough available stock on hand at this date and time the allocation table is examined to see what priority the specific MO or CO has. If it has a high priority it is still possible that it has access to material. If it still do not have access to material, the following entry for that component should be examined until a date of available material can be found.

The date of available material for a MO is then determined by the component that has the latest date of available material. The date of available material for a CO is in turn determined by the MO that has the latest date of available material.

Data extraction period

The lead time data will be collected and calculated for MOs with a CO entry date from week 30 in 2011 to week 30 in 2012. The reason that newer data cannot be used is because of that the lead time for some MO measurements are very long. This means that they will not be registered until enough time has passed. During the start of the analysis it was found that week 30 in 2012 was the last week where the data was complete for all lead time parts.

5 Empirics and analysis

In this chapter the data described in chapter 4 Data collection will be presented and analyzed As parts of the analysis is extensive it has been moved to the appendix. Areas with improvement potential will be distinguished and analyzed further.

5.1 General analysis

The observations in the production and warehouse as well as interviews with staff and management from the different departments have yielded insights into areas that are out of scope for this particular project. However these insights are interesting to investigate further in future projects and will therefore briefly be analyzed.

Data on the production time per work operation is often wrong in Movex. This makes it harder to plan the production efficiently as it is hard to get a good estimation of available capacity in production.

Another problem is how the different operations in production are categorized in Movex. There are three different "work centers" in Movex and these contain several real work centers. This means that they are in fact work groups but Movex handles them as work centers. Therefore no reporting can be done between operations making it impossible to know where in production a certain MO is. As the MOs are put away after each operation the next operation needs to know the location of the MO. Today this is handled manually by paperwork transferred to the next operation. Another result of no reporting between operations is that there is no way of knowing how much work that is left in production. This in turn means that it is hard to predict if MOs can be released to production in proximity of the current date and time.

The resolution of time data in Movex is often on a daily basis. This poses a problem when analyzing this data as well as when trying to control the production. An example of this (among many) is production time for a MO. Production is often finished the same day as it is started or the day after. When start and finish date are on the same day the difference between them is zero, implying that there is everything from no production time to one full day. When the finish date is the day after the start date the production time could be everything between a couple of hours and two full days depending on the times. This is however always viewed as two production days.

5.2 Planning efficiency

5.2.1 Planners absent from planning

During the four random consecutive weeks when this was measured, the planners only left planning at five occasions, every time to help out in the production for a short period of time, with the exception of one occasion where help was needed for seven hours. This occasion should however be regarded as out of the ordinary because several of the production staff were unavailable. The total time for the other four occasions summarizes to 4h and 12 minutes.

The measurement of the time planners are absent from production has revealed that the planners are working approximately fulltime with planning apart from a few shorter interruptions.

5.2.2 Time to deliver papers to production

The time it takes planners to deliver papers to production, in form of orders and pick lists etc., has been measured during four consecutive weeks and the result can be seen in Figure 5-1. The first two weeks belongs to one planner while the last two weeks belong to another. As can be seen the second planner spend less time than the first, and both of them have a decreasing trend. It is suspected and the planners have also confirmed that they have forgotten to fill out the form as the measurement progressed. It is also suspected, and partly confirmed, that awareness has increased among the planners of how much time that was spent delivering papers and that they were, knowingly or unknowingly, taking countermeasures.

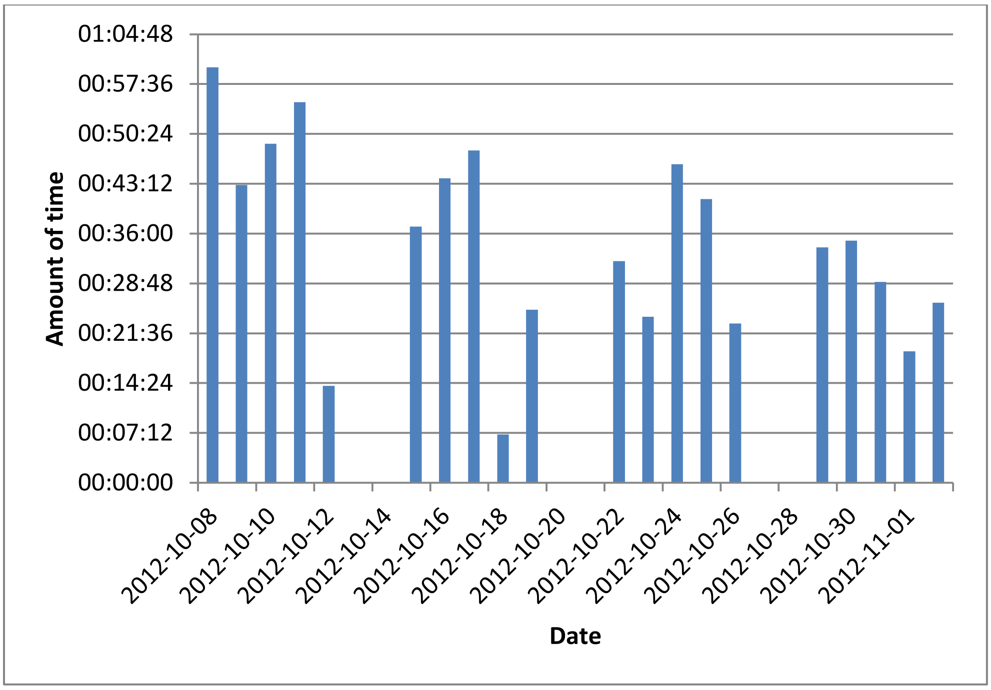

Figure 5-1: The amount of time that planners deliver papers to production each day.

The average time spent per day delivering papers to production was approximately 38 minutes for the first planner and 31 minutes for the second. The average time per day for both of them was 34 minutes and 33 seconds. However the day with the lowest registered time, 2012-10-18, the planner had to work for 7 hours in the production and therefore this unjustly brings down the average. The average time spent per week on delivering papers to production is almost three hours. The average time it took per delivery was 4 minutes and 46 seconds.

For the reasons mentioned regarding the decreasing trend, an approximation of four hours per week has been made for delivering papers to production. This represents more than 10% of the planners actual working hours which is approximately 7,5 hours per day, resulting in 37,5 hours per week.

After observing the planners it was however concluded that this is only a fraction of the time they spend on handling papers. The time it takes to print, sort and organize the papers is at least more than twice as long. With this taken in to account approximately one third of the production planners' time are spent handling papers.

5.2.3 Amount of papers used in production

The amount of papers used in production and then thrown away has been measured. The measurement has been conducted by measuring a sample of 62 MOs and then calculating an average amount papers per MO. This amount has then been multiplied by the amount of MO's started each month which has been extracted from Movex database. The result can be seen in Figure 5-2 and as can be seen there is an increasing trend. This is due to the fact that more MO's are started each month.

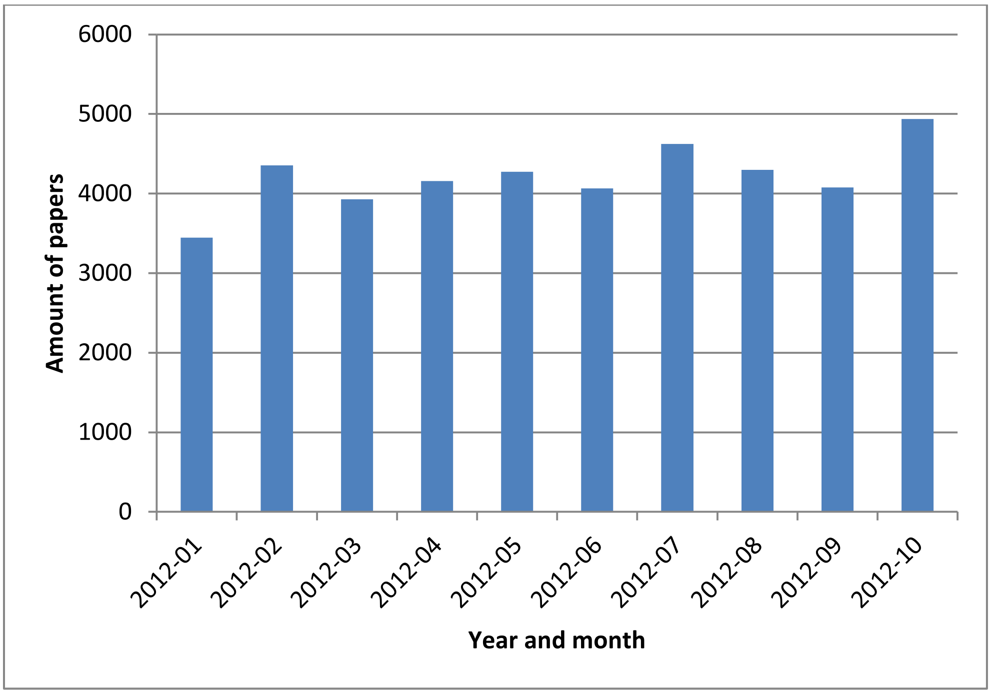

Figure 5-2: Amount of papers used in production each month 2012.

A summary of the data as well as projections on a yearly basis can be seen in Table 5-1. More than half a pallet papers will be used in production this year. The amount of papers used per year is large and does not reflect the outspoken business principal "Optimizing the use of natural resources is our business" (Alfa Laval, 2010).

Table 5-1: Overview of paper usage in production.

Amount of MOs Jan-Oct	12046
Average amount of papers per MO	3,5
Amount of papers in one pallet	90000
Approximate amount of papers Jan-Oct	**42161**
Approximate amount of pallets Jan-Oct	**0,47**
Year projection of papers	**50593**
Year projection of pallets	**0,56**

The papers printed for MOs can consist of pick lists, survey (articles that are going to be produced), operation list and a shop travel list (which shows what material and which work center that is involved). It has been pointed out that some of the documents are not even looked at in most cases. The pick list and the survey are only needed most of the time but all lists are printed anyway as there is no option to exclude specific lists in Movex. For these reasons it would be desirable to reduce the amount of papers used in production.

5.2.4 Internal DOT for planners

One measurement that has been performed is internal Delivery On Time (DOT). The information needed for this measurement was extracted from Movex database and calculated using QlikView. The graph in Figure 5-3 shows the original finish date compared to the actual finish date reported after production. The original finish date is the date that is set when the planners release a MO to production, a suggestion is made by Movex but the planners can change it before releasing the order to production. As can be seen the DOT varies quite a lot with some deep low points. The average DOT for the original finish date is 95,9% and it would be desirable to increase this as it is relatively low as well as to decrease the variability.

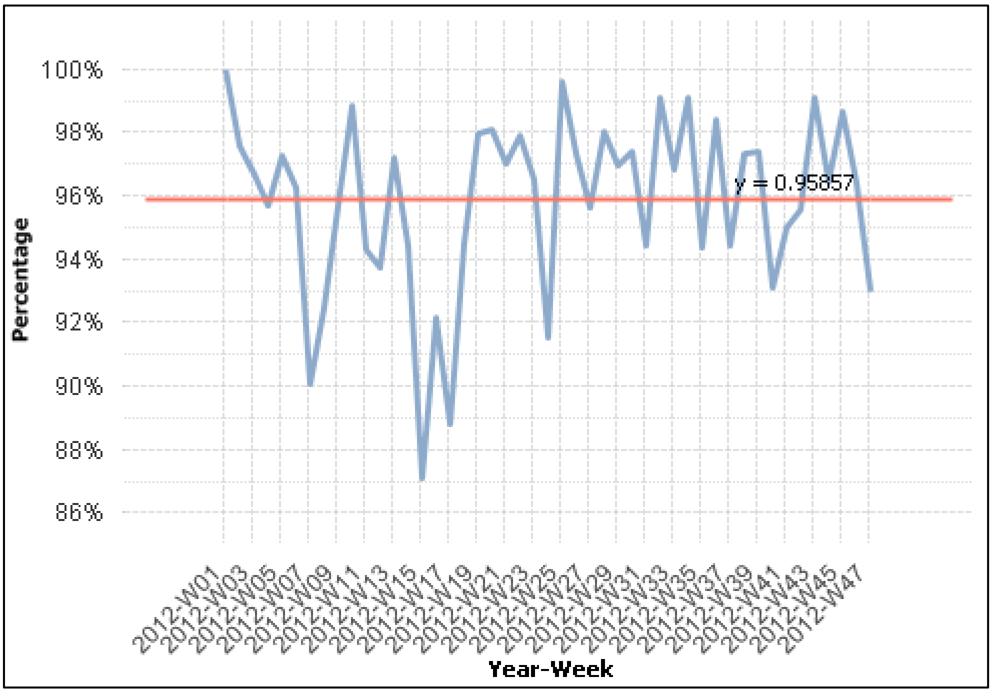

Figure 5-3: Original finish date compared to the actual finish date.

To get a clearer picture of the variability and extreme values a control chart has been made using Minitab. The green center trend line in the control chart represents the average value. The two red trend lines represent three times the standard deviation for the data series. This means that 99,73% of the values in the dataset would be inside these trend lines if the data was normally distributed (George, et al., 2004). The topmost graph in the control chart shows the variation of the individual values and the bottommost graph shows the moving range, that is the difference between two individual values.

As can be seen in the control chart in Figure 5-4, which correlates to the original finish date DOT, the low point in week 15 is outside of the three standard deviation trend line and therefore calls for more investigation. After analysis of the MOs that were late the week in question it was concluded that the main reasons was supply problems for a specific gasket but also because of equipment malfunctions. In the control chart it can also be seen that the process has a high variability.

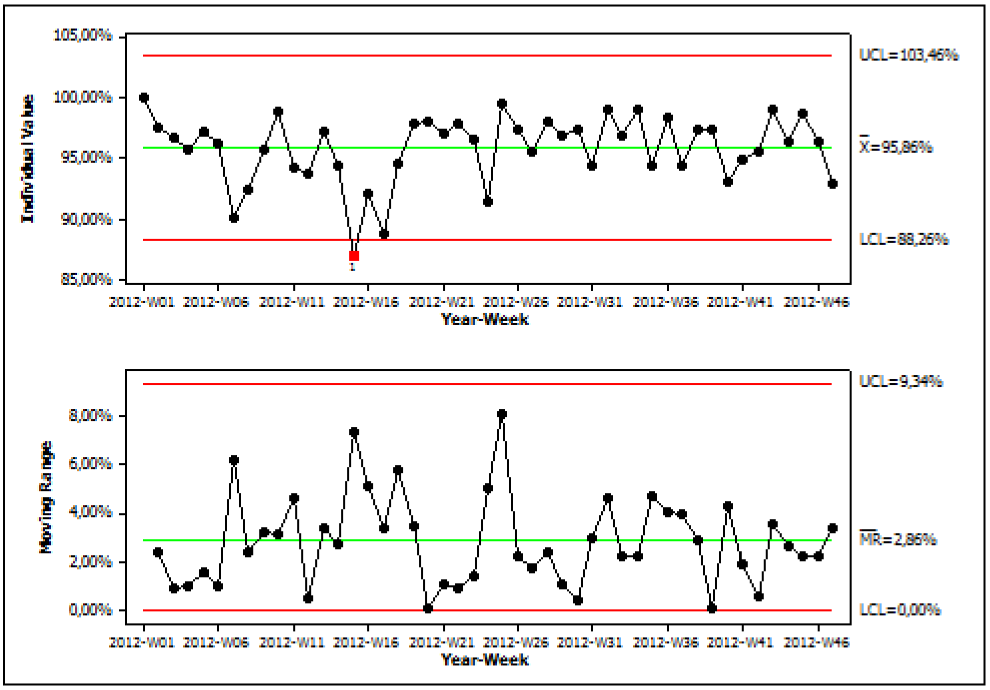

Figure 5-4: Control chart of original finish date compared to the actual finish date.

The second DOT graph, Figure 5-5, shows planned finish date compared to actual finish date. The planned finish date is the latest finish date set by the planner which means if the order has been rescheduled several times this is the last set date. In this case the average increases to 99,1% as well as the variability decreases but some low points still remain.

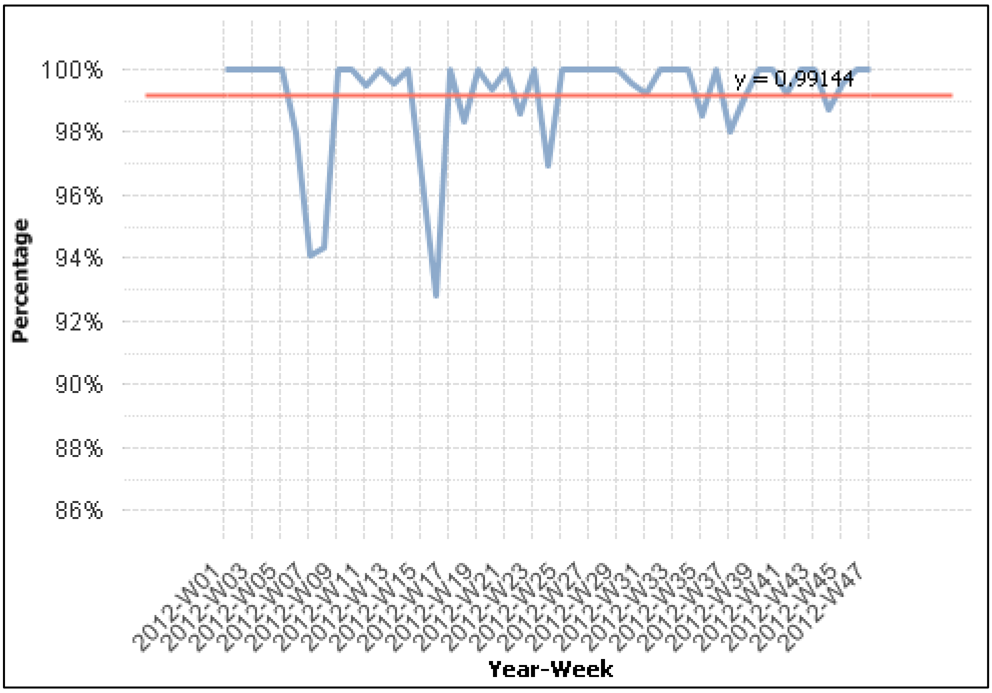

Figure 5-5: Planned finish date compared to actual finish date.

The control chart in Figure 5-6 correlates to the planned finish date DOT. As can be seen in the topmost graph there are three values outside of the three standard deviation trend lines. The first low point week seven has occurred partly due to problems in production. The next low point week eight cannot be explained as no explanations have been registered in Movex, what can be said is that the majority of the MOs that are late this week are only one day late, this was not the case for week seven. The last low point week 16 is also due to problems in production in the cases that can be confirmed. Apart from these three weeks the variability is low.

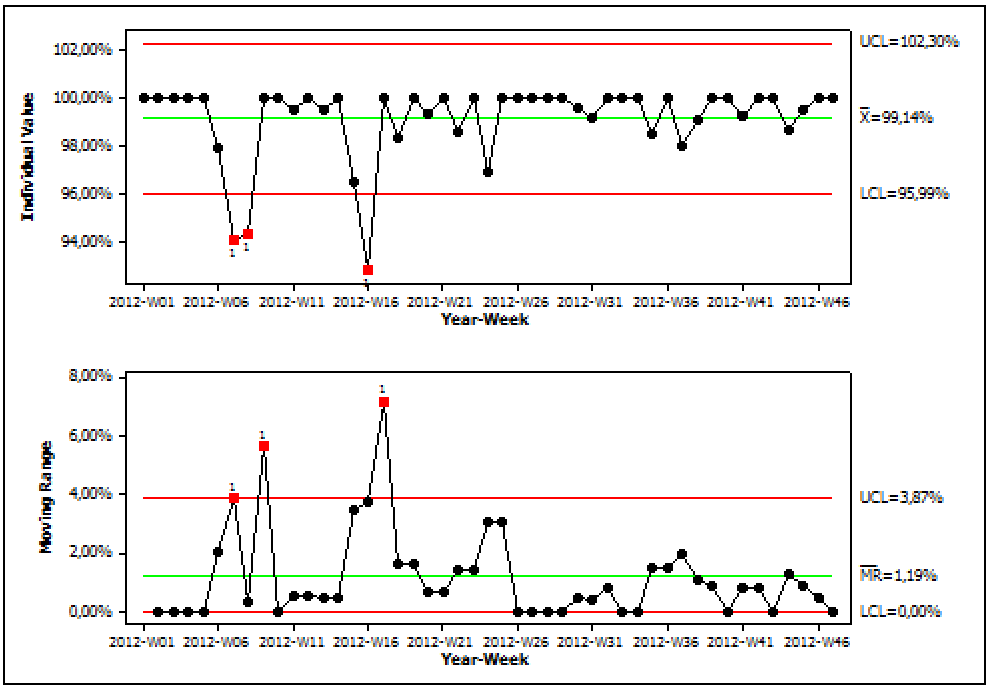

Figure 5-6: Control chart of planned finish date compared to actual finish date.

5.3 Capacity

5.3.1 Overtime in production

Figure 5-7 shows the overtime and temporary staff in production for 2012. Temporary staff for months 6-8 cannot be extracted and therefore these months only contain overtime for the ordinary staff. For this reason they are not accurate. As can be seen there is a decreasing trend towards summer and then a distinct increase after the summer months.

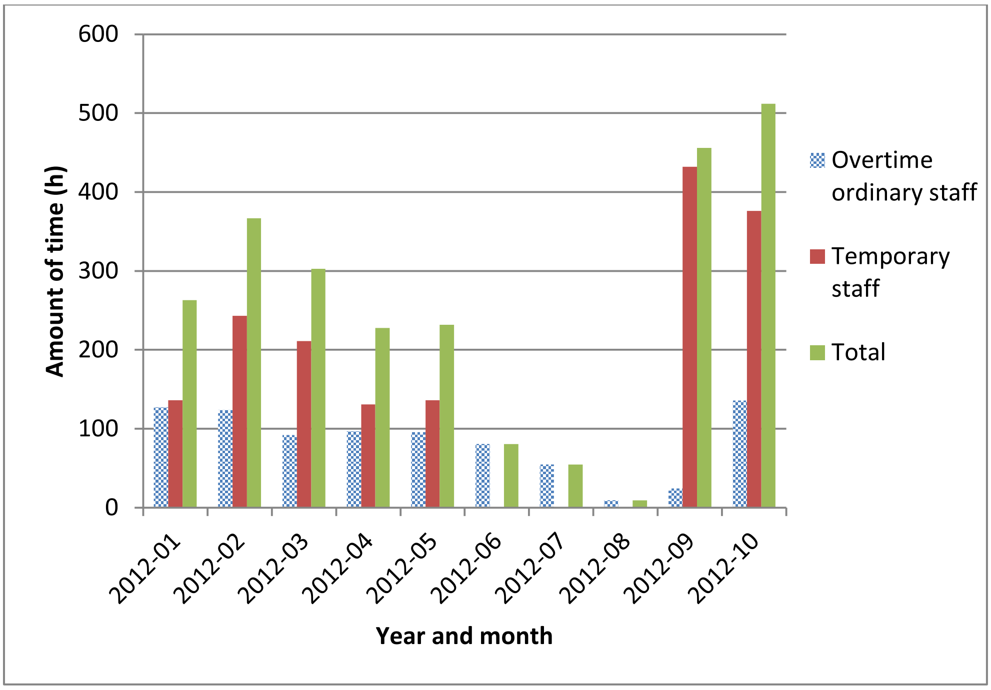

Figure 5-7: Overtime worked in production.

5.3.2 Capacity in production

Data has been collected on how many hours that are spent in production as well as how many hours that has been performed according to Movex. These have then been compared and the result can be seen in Figure 5-8, the amount of MOs manufactured each week can also be seen in the figure to the right.

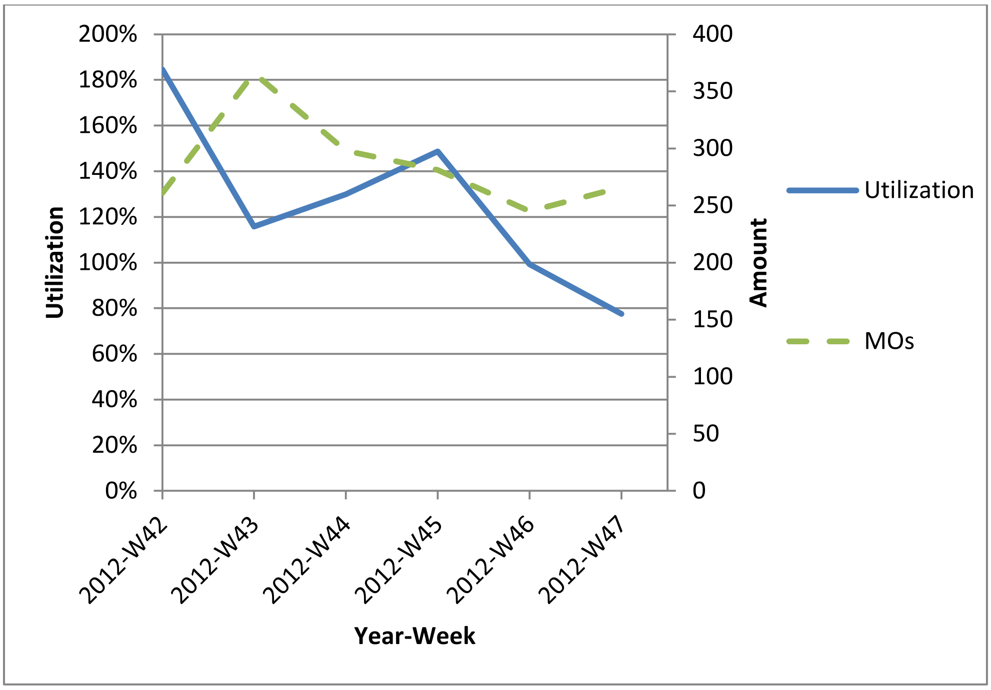

Figure 5-8: Utilization in production in comparison to the amount of MOs manufactured each week.

It is obvious that the data in Movex is inaccurate but not in a consistent way. If it was consistent, the utilization line should somewhat follow the amount of MOs line. For this reason it is hard to specify a general factor that would correct the data in Movex compared to the actual process.

5.4 Scrapped material

As can be seen in Figure 5-9, scrapping of material is done on average about 3,8 times per week. The peak in week 43 as well as in week 44 is due to a large inventory purge of obsolete products which unjustly increases the average.

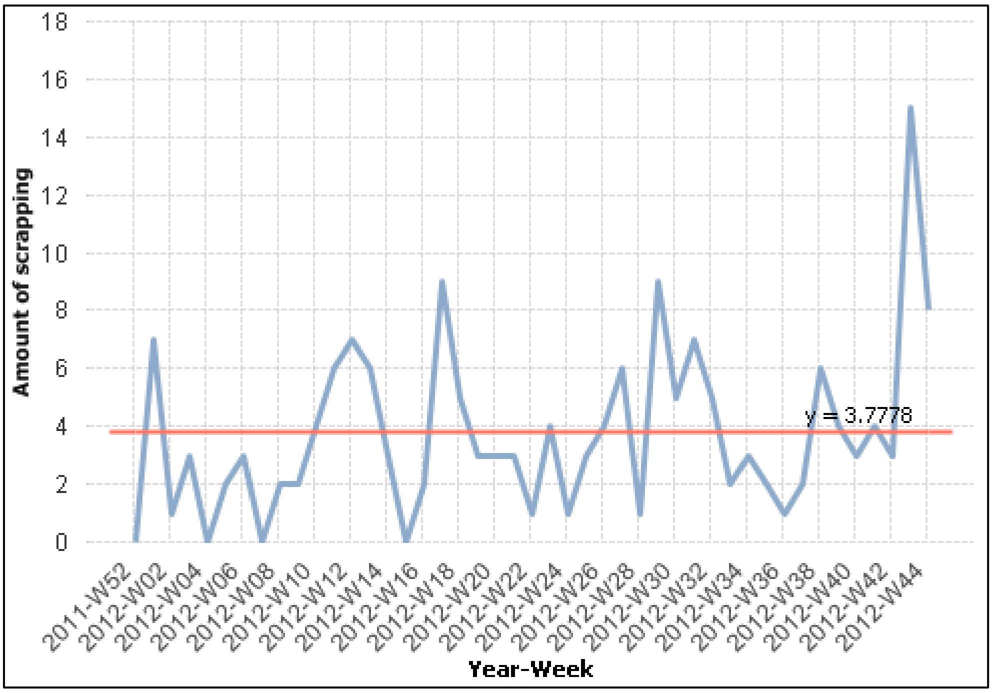

Figure 5-9: Amount of scrapping per week.

In total scrapping was reported 170 times from January to October in 2012. When comparing this to the amount of MOs during the same period, which was 12 046, scrapping can be ruled out as one of the major reasons for long lead times. Even if every single scrapping would affect two different MOs, which is known not to be the case as most of the scrapping are due to obsolete products, only 2,8% of all MOs would be affected. Putting in efforts to reduce scrapping will therefore most probably not be efficient when it comes to lowering the lead time to customers.

5.5 Lead time

5.5.1 Data validation

When calculating the material available date for all MOs on a CO, sometimes a component was missing data. If a MO was missing a material available date on one component, it is not possible to create a material available date for that MO. This in turn led to that if a CO was missing a material available date on one MO, the whole CO could not get a material available date. For this reason some of the data population was removed due to lack of dates on some COs. The amount of COs removed were 436 and this represents 8,0% of all COs during the time period 2011 week 30 to 2012 week 30.

To make sure that the selection accurately represents the population some tests and plots has been performed to ensure consistency. As COs with many MO rows have a higher probability that they will be removed it is important to make sure that all large COs was not removed or that other distortions of the data was unintentionally made. The amount of MOs per CO has therefore been chosen as the main investigation point as this is most vulnerable to the selection. The amount of COs, mean of MOs per CO and standard deviation can be seen in Table 5-2.

Table 5-2: Statistical comparison of population and selection.

	Amount	Mean	StDev
Population	5444	2,30	2,79
Selection	5008	2,22	2,74

As can be seen the mean is not exactly the same but still close enough to represent the population. The standard deviation is also close and therefore so far the selection seems to be representing the population. To compare the distribution of the two datasets histograms as well as a boxplot has been created. The histograms can be seen in Figure 5-10 and Figure 5-11. Although the amounts are lower in the histogram of the selection, the histograms have the same shape, which is satisfactory.

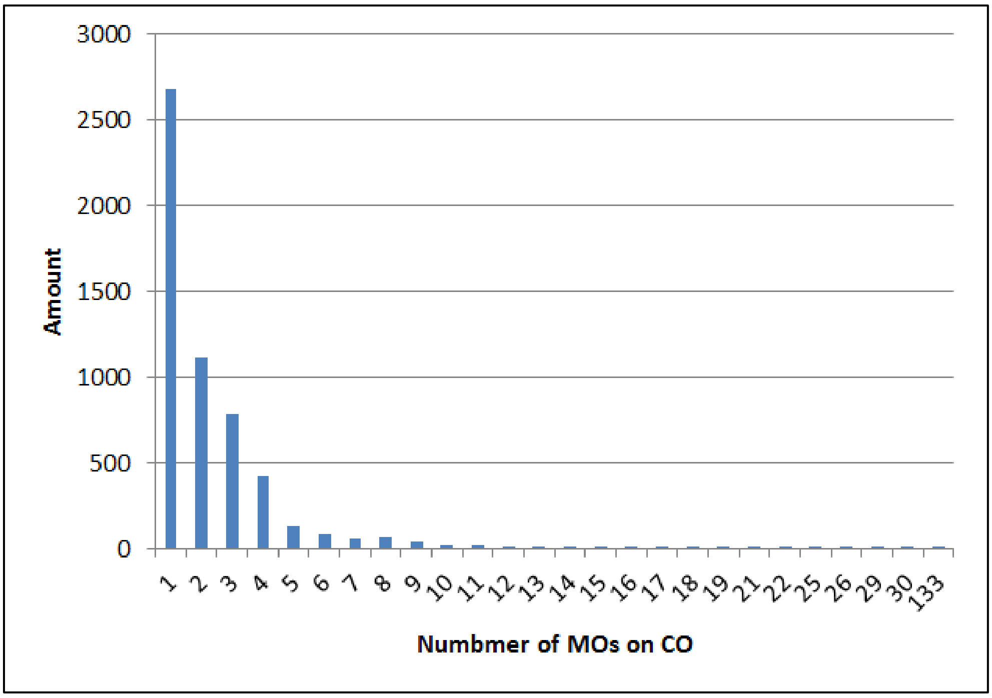

Figure 5-10: Histogram of population.

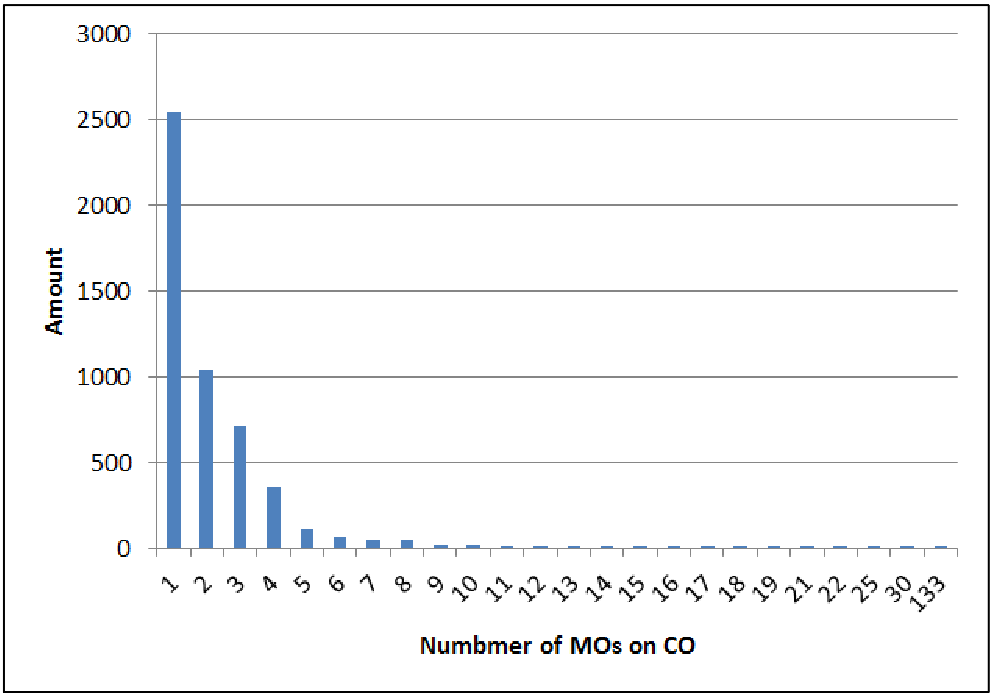

Figure 5-11: Histogram of selection.

The boxplot in Figure 5-12 is also satisfactory, the distribution of values is almost identical. However the median value changes from two to one. This is due to the fact that the population is very close to a median of one and small changes would change it. This has happened in the selection which in turn is very close to two in median. The mean value presented in Table 5-2 confirms that the data series are close to each other.

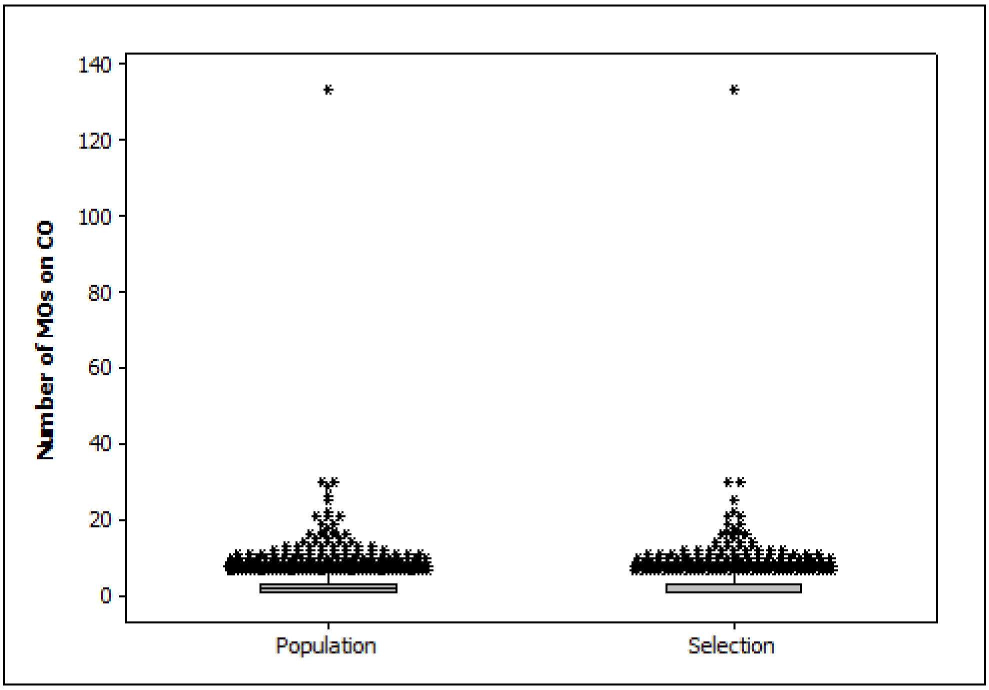

Figure 5-12: Comparison of population and selection as distribution in a boxplot. There is no dimension on the x-axis, the widths only purpose is to display all values.

To conclude, the selection is in a satisfying way representing the population. In some of the measurements, when it is possible, the population will be used instead of the selection.

5.5.2 Measures

In this chapter an overview and definition of the divided lead times will be presented. The different lead time parts are as follows.

T1, Waiting time before release to production:
This is defined as MO entry date and time subtracted with CO entry date and time. MO entry is when planners release an MO to production and CO entry is when a CO is received from the customer and registered in Movex.

T2, Waiting time for material to become available:
This is Date and time of available material subtracted with MO entry date and time.

T3, Waiting time to start when material is available:
This is Actual start date subtracted with Date of available material, where actual start date is the date when production for the specific MO is started.

T4, Total time from release to start:
This is Actual start date subtracted with MO entry date.

T5, Production time:
This is Actual finish date subtracted with Actual start date, where actual finish date is the date when production is finished and the MO is put away.

T6, Waiting time after production:
This is Finish day subtracted with Actual finish date, where finish day is day of transportation subtracted with any potential internal administration lead time (in days) for the specific route.

Transportation time:
This is not an actual measurement but data collected from routes from Movex database and therefore this will not be analyzed in depth.

Internal lead time:
This is Actual finish date subtracted with CO entry date. The reason that Actual finish date is used instead of Finish day (as defined in T6 above) is that T6 includes waiting time for transportation. Waiting time in T6 should therefore not be included in internal lead time.

Total lead time:
This is Date at customer subtracted with CO entry date, where date at customer is a calculated date from actual finish date with regard to the used route.

Days too late from CRD:
This is Date at customer subtracted with CRD. When the MO is early (and therefore the measurement would have negative time) the time is set to zero.

Difference between earliest and latest MO material available date**:**
This is the largest difference in Date and time of available material between all MOs on a CO.

5.5.3 Graphs

In chapters 5.7 and Appendix a set of three graphs will reoccur several times and because of this they will be explained below to avoid repetition.

The first graph that will be presented is the week average graph. This graph shows the average amount of days per MO per week as a bar chart for the specific measurement. There will be two trend lines in this graph, one solid orange line which is the average of the week average. There will also be a red dotted trend line and this line represents the average of all values for the specific time period. This graph is powerful when assessing the variability of the measurement as well as trends.

The second graph plots the distribution of days for the specific measurement. This graph simply illustrates the distribution of the dataset. If there is a trend line in the graph it is an exponential trend line fitted to the data.

The third and last graph is a boxplot. A boxplot is effective in illustrating many things, for example the distribution of values. The top light blue trend line follows the maximum values for each week. The green trend line shows the average per week (same values as the first graph). The top whisker = Q3+1,5*(Q3-Q1) or the top most value under this point. The top point of the box is Q3 and at this point 75% of all values are under it. The middle black line in the box is the median and the bottom point of the box is Q1 which has 25% of all values under it. The bottom whisker = Q1-1,5*(Q3-Q1) and the minimum values are marked with an orange dot.

If nothing regarding timespan is mentioned in the measurements it is from year 2011 week 30 to year 2012 week 30 by default.

5.5.4 Lead time analysis

As the lead time analysis is extensive and detailed it will be presented in chapter Appendix A: Lead time analysis. In chapter 5.5.5 a summary of the analysis will be presented.

5.5.5 Summary of lead time measurements

A graphical overview has been created to illustrate the measurements which can be seen in Figure 5-13. The values behind this figure are the same as the ones presented in Appendix A: Lead time analysis for each measurement. The selection CRD a.s.a.p. has been made as intentional waiting time would otherwise be present in the total lead time. The sizes of the measurements in the figure represent their part of the total lead time. This graphical overview is a powerful tool in determining where the largest parts of the lead time are positioned. It is also effective in providing an understanding of the lead time process.

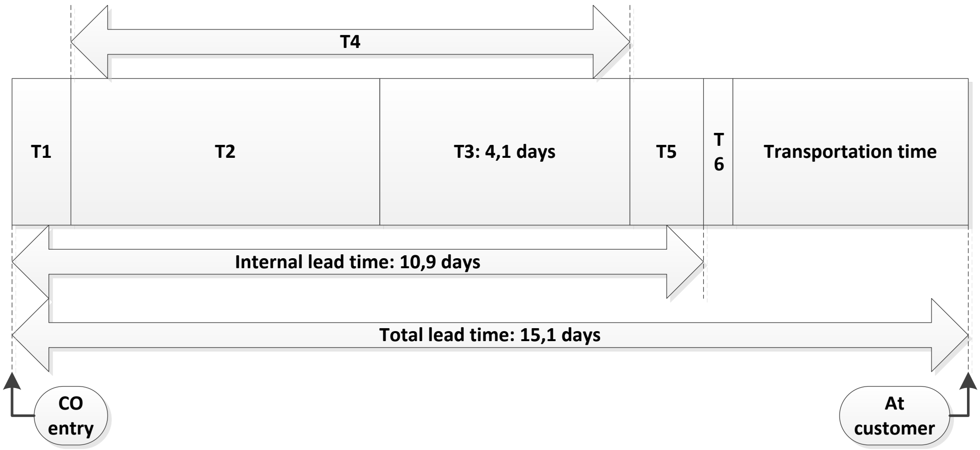

Figure 5-13: Overview of measurements, sizes roughly matching average times with CRD a.s.a.p. Total lead time is 15,1 days.

T1, Waiting time before release to production

The time it takes to release MOs to production is low in general, especially when material is available from CO entry where it only takes 0,39 days on average. One should note that 0,39 days equals 9,36 hours, but COs can arrive all hours of the day while the production planners only work daytime. That means if a CO arrives late in the afternoon it will wait to the next morning before being processed. As the case when material is available from CO entry is the only case that can be improved in the scope of this project, and it is already satisfactory, no further investigation of this measurement will be performed (as supplier improvements will not be made).

T2, Waiting time for material to become available

This measurement is by definition only interesting when material is not available from CO entry and CRD is as soon as possible. This is because when CRD is realistic purchasing will in some cases set a request date for material further ahead to reduce tied up capital. Therefore waiting time would be included in the measurement if CRD was realistic. The average waiting time for material to become available is 10,59 days. The average waiting time per week also has high variability with an increasing trend. This will however not be given any further consideration as supplier improvements will not be made. Although it is interesting to measure as it is the largest part of the total lead time to customers.

T3, Waiting time to start when material is available

For the general case for this measurement, the selection of data is all MOs that have a calculated material available date, an actual start date and CRD a.s.a.p. If CRD was realistic waiting time would be included in this measurement. The average waiting time for a MO in this selection, from the moment that all MOs on a CO were available until production was started, was 4,12 days. The variability per week is higher in the beginning but all in all it is low. When material is available from CO entry date the average waiting time decreases to 3,32 days. When material is not available from CO entry date the average waiting time increases to 5,01 days. This means that after having waited for the suppliers to provide the material, production waits even longer to start producing after receiving material than they do if the material is available from start. This means that internally, on average, another 1,69 days are added to the lead time.

This measurement is very interesting as a large part of the lead time is positioned here in all cases, see Figure 5-14 and Figure 5-15 (where T3 is this measurement). It is also interesting as it is pure waiting time and countermeasures could potentially have a large impact. For these reasons this measurement will become one focus point and improvements will be created.

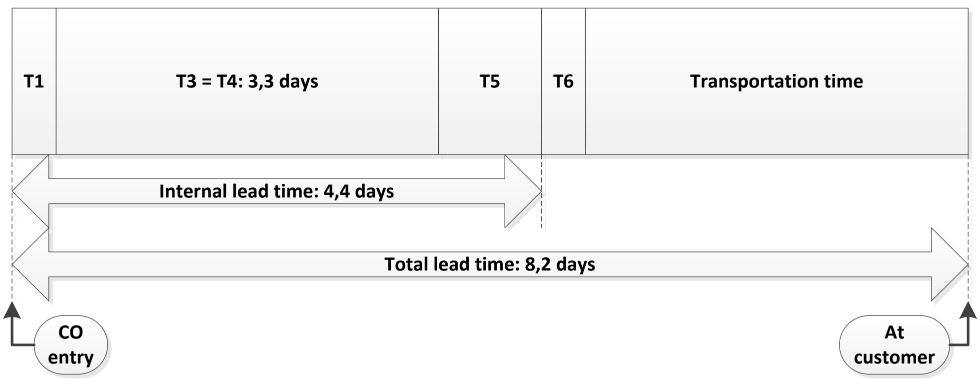

Figure 5-14: Overview of measurements, sizes roughly matching average times with CRD a.s.a.p. and material available at CO entry. Total lead time is 8,2 days.

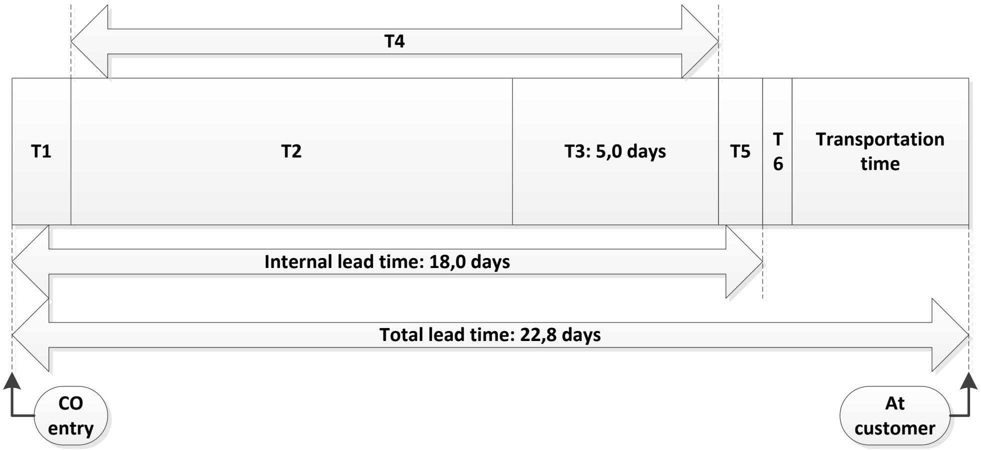

Figure 5-15: Overview of measurements, sizes roughly matching average times with CRD a.s.a.p. and material not available at CO entry. Total lead time is 22,8 days.

T4, Total time from release to start

In this measurement the selection that customers want delivery as soon as possible has been made. The average time is 12,99 days with a large variability. The objective with this measurement is to get an overview of the total time from the release of MOs to the start of production and is thus not interesting from an analytical standpoint.

T5, Production time

In this measurement all MOs with a start and finish date has been included. This measurement has one day as resolution and because of this, if a MO is started and finished the same day, it is assumed to have taken 0,5 days in production time. If this assumption was not made many MOs would not take any time at all to produce. The average production time is 1,16 days which is low.

The production time is stable, low and only represents a small portion of the internal lead time. As this is satisfactory no further investigation of this measurement will be performed.

T6, Waiting time after production

The average waiting time after production are 1,48 days. This measurement is on a daily basis, so if a route has a departure on the same day as the production is finished, the waiting time will be zero. This means that if the production is finished after the departure time, but on the same day, the waiting time will still be presented as zero in the results. The waiting time in this measurement must therefore be seen as a best case scenario. When customers request delivery as soon as possible the average waiting time after production decreases to 0,47 days, which is not very long, so this must be seen as satisfactory.

When customers request delivery on a specific realistic date the average waiting time after production increases to 6,56 days. Having these MOs waiting when finished, with much value added to them, for almost a week on average before being transported is not very lean. This tie up a lot of capital as well as the longer a finished product is being stored, the risk of it being damaged increases. This is however out of scope as it does not affect the lead time.

Internal lead time

When measuring the internal lead time all MOs with a realistic CRD have been removed, this is because if CRD is realistic waiting time would be included in the measurement. The average internal lead time is 13,39 days.

When material is available from CO entry the average internal lead time decreases drastically to 4,38 days. Of the 4,38 days internal lead time, 3,32 days are in average spent waiting for production to start which is unnecessary. In other words 75,8% of the internal lead time is spent waiting in this step.

When material is not available from CO entry the average internal lead time increases to 17,00 days. The amount of time that is spent waiting for production to start increases to 5,01 days after material has become available. The increase is due to the fact that the system specifies two days for receiving and put away when in reality this often is made the same day as the material is received. This in turn hinders the planners from rescheduling the MO in advance, instead rescheduling has to be performed when material is registered as available on a location. This does not change the fact that the MO still waits a long time for production to begin.

This purpose of this measurement is mainly to get an overview of the process time.

Total lead time

This measurement is performed for the same reason as internal lead time. The difference is that waiting time after production as well as transportation time has been taken into account. The average total lead time when customers request delivery as soon as possible is 17,88 days. When material was available from CO entry date the average total lead time was 8,19 days. When material was not available from CO entry date the average total lead time increased to 21,73 days.

Days too late from CRD

This measurement shows how well the CRD is fulfilled, which is done for 73,6% of all MOs with a realistic CRD. When material was available from CO entry, the longest time a MO was late was 10 days, while when material was not available from CO entry, the longest time a MO was late was almost 70 days. The difference in average values, 0,57 and 3,52 days, also contributed to the conclusion that the supplier lead time is the main reason that CRDs are not fulfilled. Because of this no further investigation of this measurement will be performed (as supplier improvements will not be made).

Difference between earliest and latest MO material available date

In this measurement the selection material not available from CO entry as well as CRD as soon as possible has been made. If material was available from CO entry the measurement will be zero and when CRD is realistic the measurement should be as long as possible in some cases, i.e. when some components are in stock and others should be ordered. The average difference is 4,98 days which is acceptable, however not desirable. When studying the distribution the amount of zero values stand for 65,7% of all values, which is desirable. This means that when material arrives it is synchronized.

No further investigation of this measurement will be performed (as supplier improvements will not be made).

Observations

One thing is apparent when analyzing the different measurements, as soon as suppliers are involved the process times and variability increases substantially. For this reason this could be interesting to investigate in future projects. Another observation is that the transportation time is a large part of the lead time and for this reason this could also be interesting to investigate in future projects.

5.6 Summary and chosen focus points

In this chapter the analysis of measurements will be briefly summarized and focus points for further analysis will be determined.

General analysis

It would be preferable if Movex would support exact time instead of dates and that the production time for each operation was correct. It would also be preferable if the different work centers were divided according to the actual production operations.

Planners absent from planning

As the planners are working approximately fulltime with planning apart from a few shorter interruptions to help out in the production, the production planning must be considered as a fulltime position.

Time to deliver papers to production

The planners are spending approximately one third of their time on handling papers. This is too much time to spend on doing something that does not add value to the customer. An easy solution to this would be to print the papers in the production. Although this would mean that someone from production would have to sort the MO papers instead. Since most of the papers are not used, a better solution would probably be to invest in monitors of some sort, at each workstation, so that papers would not have to be printed out as well as only relevant information was shown. As parts of the IT infrastructure needed are already in place this would probably not be that hard or expensive to install. As discussed in chapter 0 As mentioned in Data extraction period in chapter 4.2.4 Lead time the lead time data extracted is from week 30 in 2011 to week 30 in 2012.

Waiting time before release to production, the time it takes planners to release MOs to production have a low impact on the lead time. Making improvements here would therefore not have a significant impact on the lead time. For this reason no further investigation will be made on this measurement.

Amount of papers used in production

A very large, unnecessary amount of papers are used in the production. The papers would be unnecessary if a digitalized system, as described above, was introduced. As with the Time to deliver papers to production measurement, no further investigation of this will be performed, since this part of production planning has a low impact on the lead time.

Internal DOT for planners

As the lead time for release to production is short, no improvements will be made to planning. Therefore this will not be a chosen focus point.

Overtime in production

A large amount of overtime is being used in the production. It is desirable to have some flexible staff to be able to reduce the workforce if the demand is low. But if there always is a large amount of overtime perhaps one or a few more ordinary staff could be hired in order to reduce the cost. From the data gathered not much can be said about this, and as this does not impact the lead time, no further investigation will be made on this measurement.

Capacity in production

The inconsistency of the accuracy of production times for MOs in Movex makes it hard to define how much work that should be planned for each day. For this reason it will be hard to plan the capacity utilization in production. To be able to plan production more accurate in comparison to the capacity, the data on production times would need to be corrected first. However, since there is a policy that the capacity should not be the critical factor when planning production, focus will not be set on utilizing the capacity better and thus no further investigation will be made on this measurement.

Scrapped material

As scrapping is done very seldom in comparison to the amount of MOs that are produced, it has been concluded that scrapping can be ruled out as one of the major reasons for long lead times.

Lead time

The full lead time analysis can be found in Appendix A: Lead time analysis. As mentioned in chapter 5.5.5 Summary of lead time measurements, Waiting time to start when material is available (for MOs that have CRD a.s.a.p.) has the largest impact on the lead time, within the scope of the project. For this reason, focus will therefore be set on reducing this waiting time.

5.7 Further analysis of waiting time to start when material is available

As waiting time to start when material is available was chosen as a focus point this will be analyzed further. After analyzing this waiting time deeper it was concluded that it could be divided into two separate measurements as can be seen in Figure 5-16. The first one is the waiting time from that material was available (or from MO entry date when material was available from when the CO was created) to the planned start date. This means that this is planned waiting time to start production. The second part of the waiting time is from the planned start date to when production was started (actual start date). The measurement actual to planned finish date is also presented in Figure 5-16 although it is not a part of the waiting time to start when material is available. It is however interesting to observe as it is closely connected to the second part (planned to actual start date) of the waiting time to start when material is available. The reason they are connected is because if the production lead time is altered, both of these will be affected.

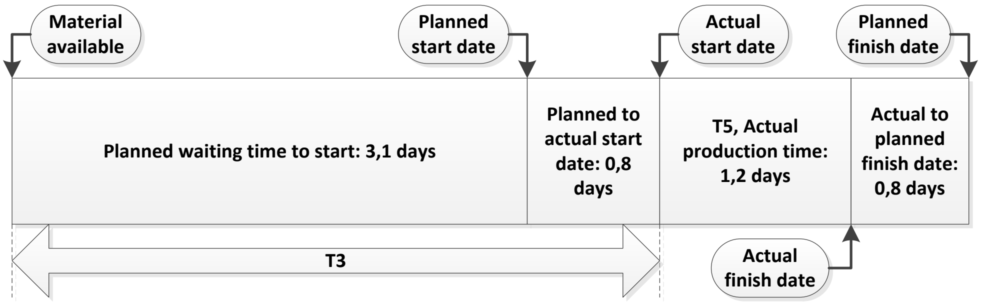

Figure 5-16: Overview of the waiting time before and after production, sizes roughly matching average times with CRD a.s.a.p.

The time from actual to planned finish date will from now on be included in the internal lead time as this is a more correct way of measuring it, as transportation departs on the planned finish date. It would have been desirable to have done this from the beginning of the measurement, although this would however fundamentally change the previous measurements and will therefore not be changed. This will instead be done from this chapter and forward.

Unlike the previous measurements and analysis in chapter 5.5 Lead time, the time period examined in this chapter will be 2012. This is because for the first measurement large outliers in the end of the timespan will be included in the data as the planned start date is set when a MO is released to production. For the second measurement very large outliers will not be included in data, this is however not a problem since there have not been any extreme outliers in the past. When analyzing the very last few weeks, it is important to remember that larger outliers might exist but have not been registered in the data.

5.7.1 Planned waiting time to start production

This waiting time has been examined for the case when material was available for all items on a CO from that the CO was created as well as for the case when material arrived later. It is only interesting to examine this waiting time when customers request delivery as soon as possible, otherwise waiting time should be in this time period.

General case

When customers request delivery as soon as possible, which is the case for 84,4% of all MOs, the average planned waiting time to start production was 3,14 days, as can be seen in Figure 5-17. The average waiting time has a high variability without any clear trends.

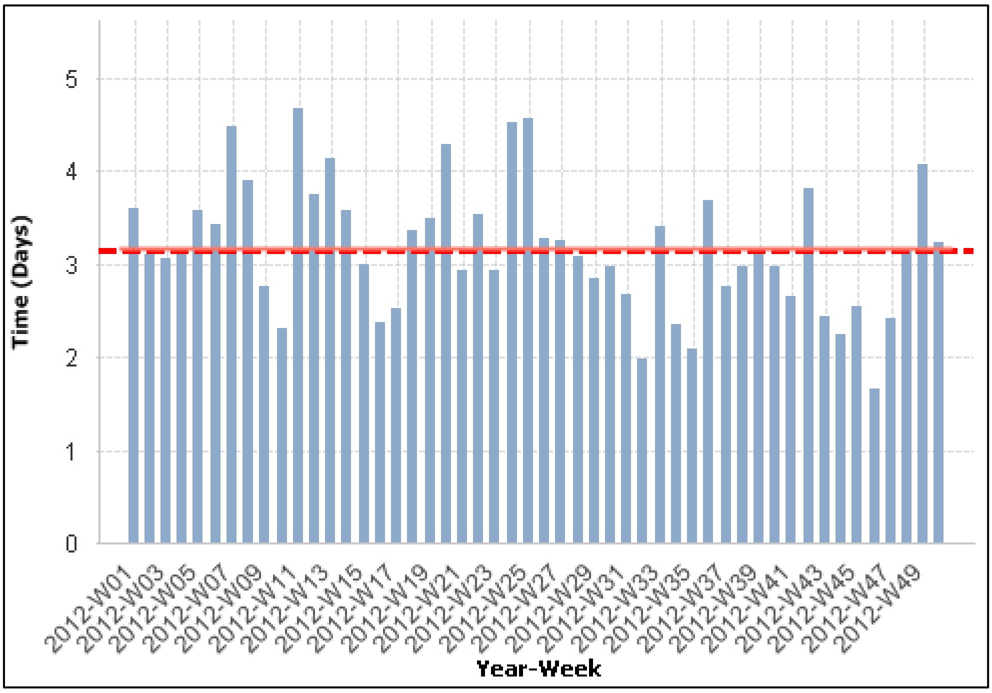

Figure 5-17: Average amount of planned waiting time to start production in days per MO per week.

The distribution that can be seen in Figure 5-18 shows that the majority of values are located at one day, which indicates that planners most often release MOs to be started in production on the next day. Although in many cases production is planned for a later date.

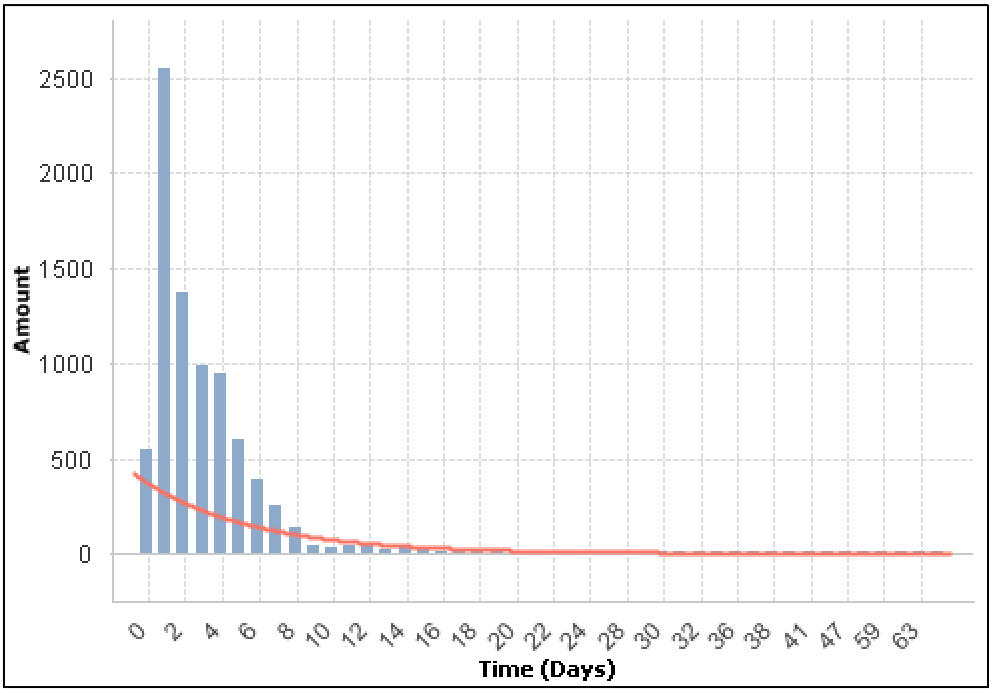

Figure 5-18: Distribution of planned waiting time to start production in days rounded to integer.

In the boxplot in Figure 5-19 it can be seen that the process has some variability, with some large outliers.

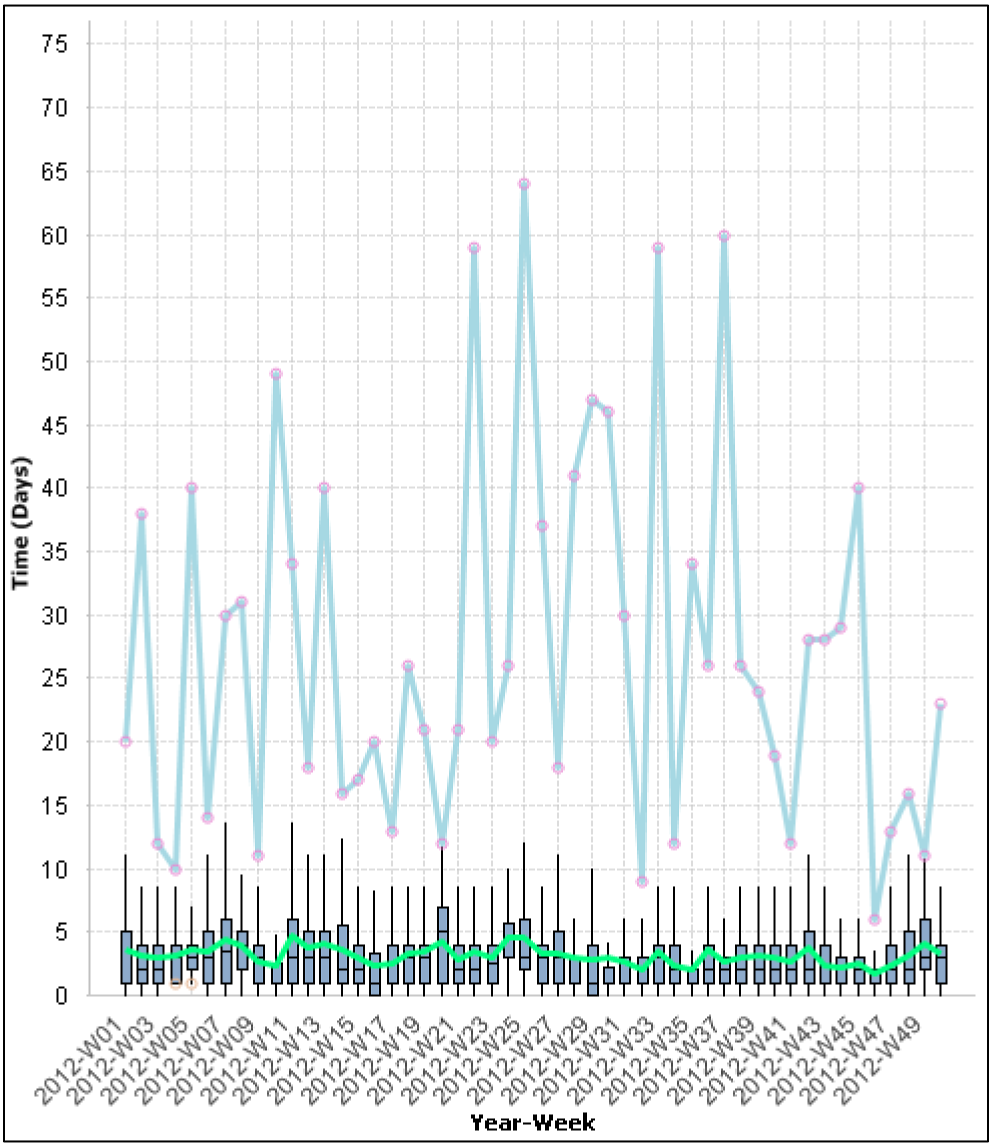

Figure 5-19: Boxplot of planned waiting time to start production in days per week.

Other selections

In the case when material was not available from CO entry date the average planned waiting time was 3,45 days. As the graphs are similar to the general case they will not be presented. The increase in time from the general case is partly from that material becomes available earlier in reality than what the system and the planners have planned for. For some MOs material can have been delivered earlier, however if it arrives much too early the production planners often reschedule the start date to an earlier date. Despite of these reasons there is still waiting time that is unaccounted for.

The case when material was available from CO entry date the average waiting time was 2,63 days. Apart from this the graphs are similar to the general case.

Origin of waiting time

This measurement has been analyzed further to be able to understand where this waiting time originates. After observing the planning process as well as investigating several MOs it could be ruled out that Movex was proposing incorrect start dates. The start date that Movex proposes takes potential purchases, customer request dates, route departures etc. into account and sets the correct start date. After interviewing the production planners it was concluded that the start dates were postponed when there was lack of capacity in production. As no other major reasons were found it could be determined that the planned waiting time to start production is due to that production planners postpones the start date because of lack of capacity in production.

5.7.2 Difference in planned and actual production lead time

This measurement is by definition interesting to observe regardless of CRD and material availability. Stratifications on these have been performed although nothing of value was found. This measurement has correlation with production lead time. This is because if the production lead time is longer in Movex then in reality, production could choose to wait to start production and still be finished on the correct day. The same applies when production starts the correct day and therefore finishes too early. As the different work centers have different production lead times this would be interesting to stratify on. Therefore stratifications have been done on work center and production lead time.

General case

When no stratifications has been done the average waiting time from planned to actual start date is 0,85 days as can be seen in Figure 5-20. The average waiting time from actual to planned finish date is 0,75 days as can be seen in Figure 5-21. The variability is large in both cases and it is clear that the two cases roughly complement each other meaning that when one has a low value the other one has a high value. As these values have a close correlation and the same origin they will be added for the rest of this chapter to get an overview of the measurement. The result of the added averages can be seen in Figure 5-22. As can be seen the variability is low and on average the production lead time data is 1,58 days too long, which means that the lead time to customers is unnecessarily 1,58 days too long. It is important to remember that the last weeks could have higher values as extreme values will not be included.

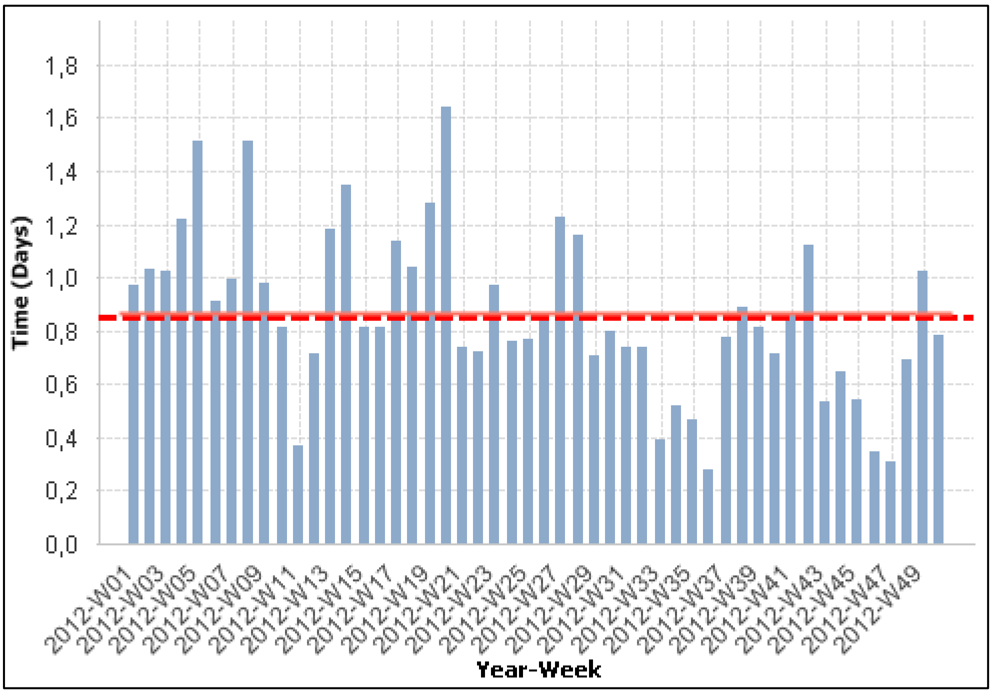

Figure 5-20: Average amount of waiting time from planned to actual production start date in days per MO per week.

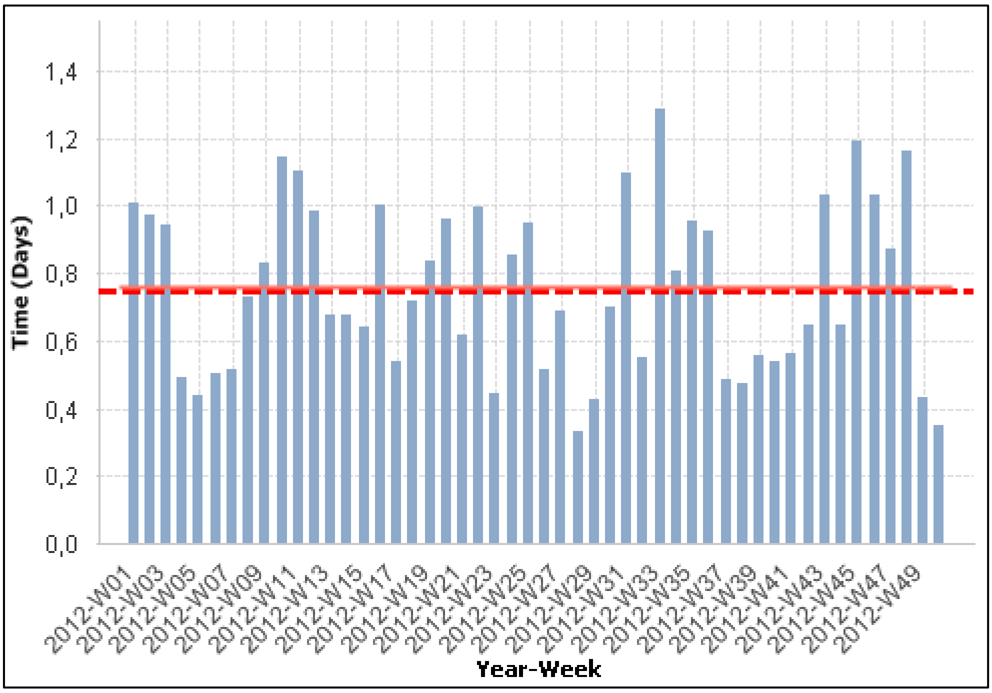

Figure 5-21: Average amount of waiting time from actual to planned production finish date in days per MO per week.

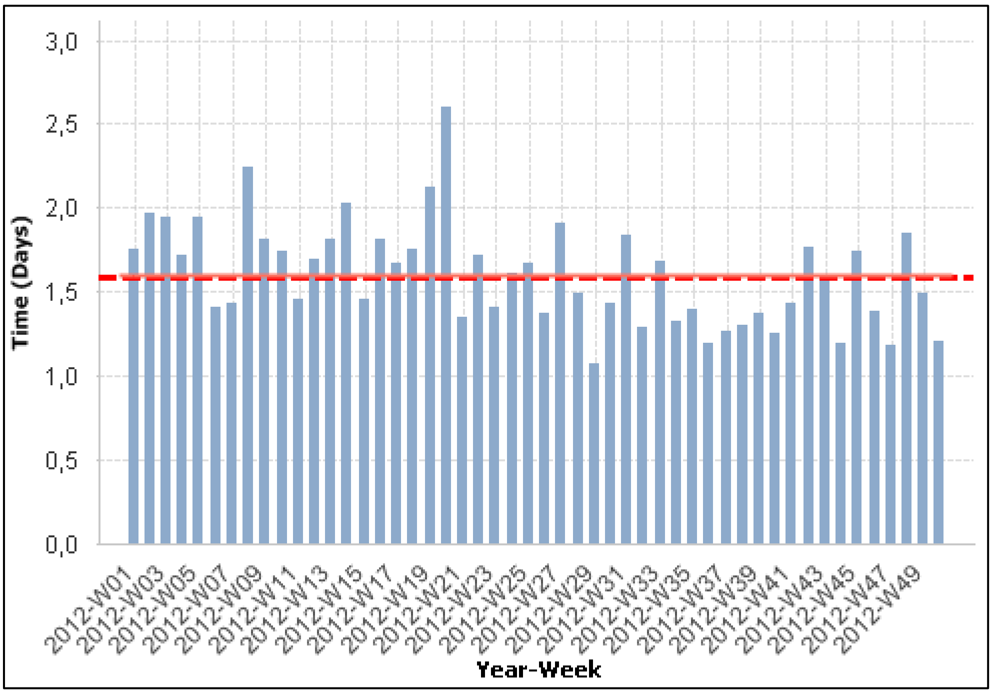

Figure 5-22: Average difference in planned and actual production lead time in days per MO per week.

The distribution in Figure 5-23 reveals a large weight at one day. The amount of MOs that have the correct production time is substantially smaller than the amount that does not have the correct production lead time. If a MO is started on the planned start date and the production lead time is too long it will be finished too early and therefore the lead time could be reduced. On the other hand if the production starts late and still is finished in time it could instead start on the planned start date and be finished earlier reducing the lead time. For these reasons it is important to have the correct production lead time in all cases.

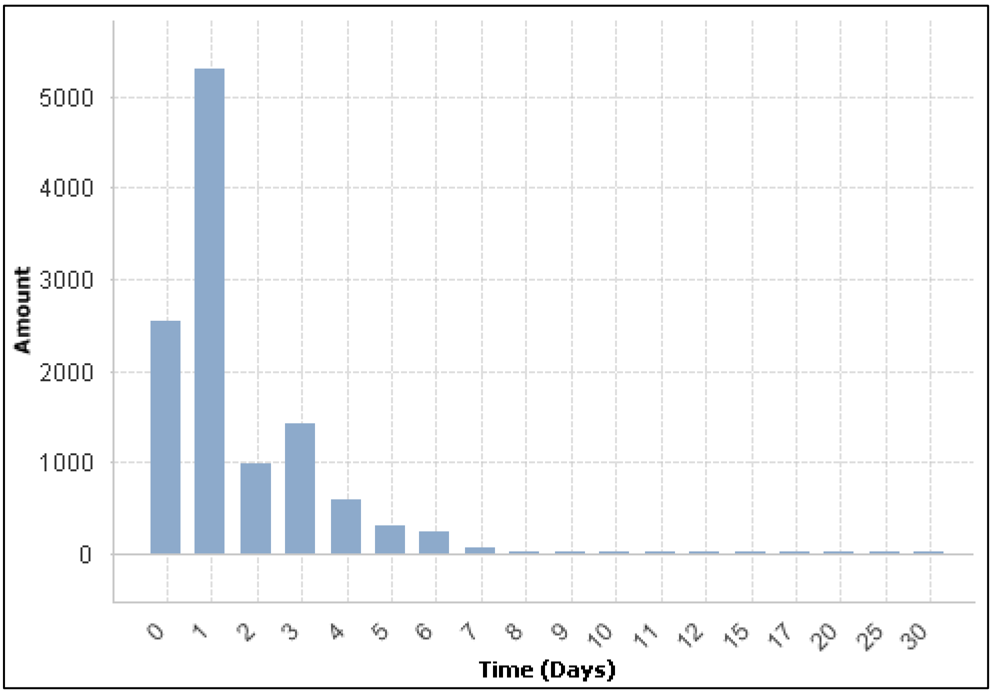

Figure 5-23: Distribution of difference in planned and actual production lead time in days rounded to integer.

In Figure 5-24 it can be seen that the distribution of values are changing between the weeks although the weight of most weeks is positioned from one to three days.

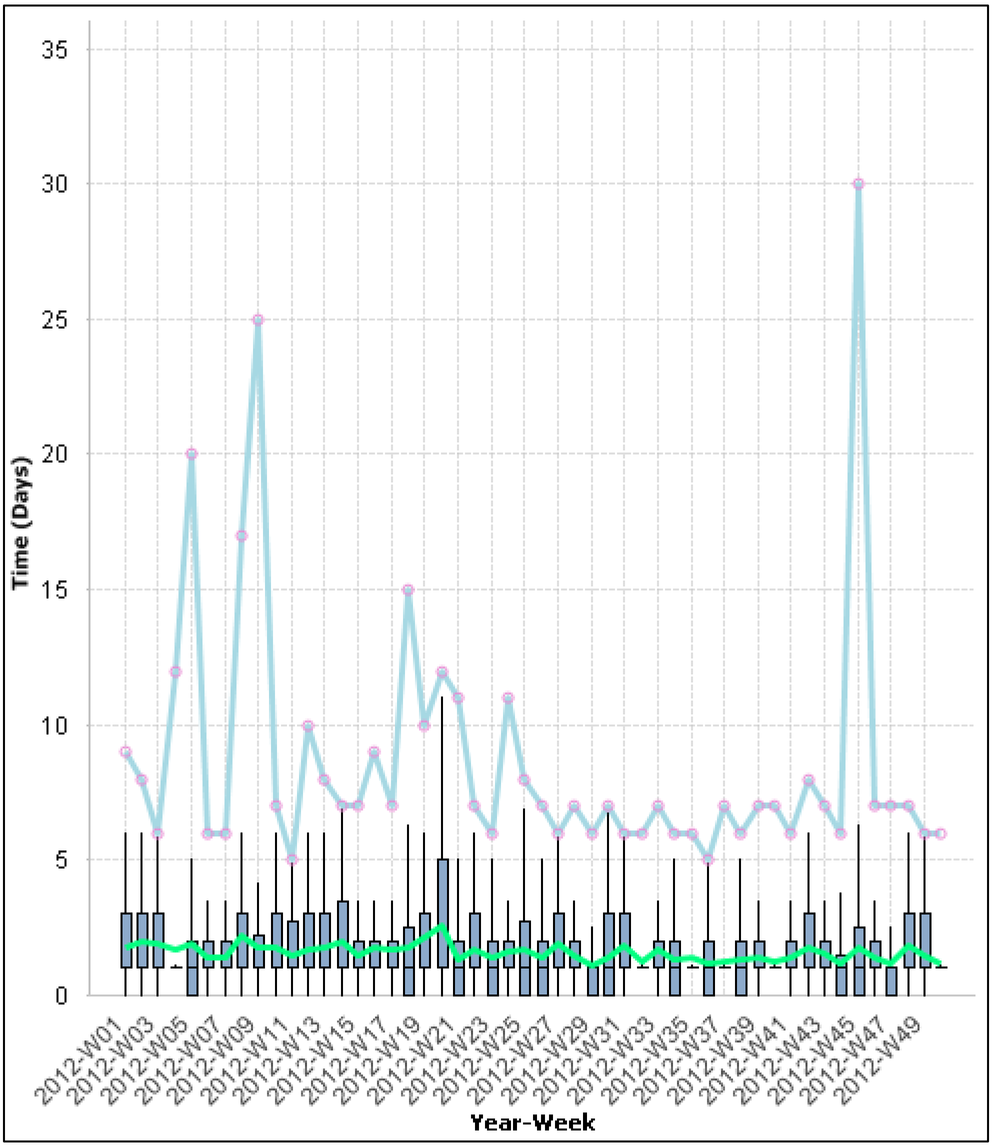

Figure 5-24: Boxplot of difference in planned and actual production lead time in days per week.

Selection work center X10

This work center stands for 43% of all MOs. Examination of the MOs that have been produced in the X10 work center showed that the graphs were similar to the general case, these graphs will therefore not be included in the report. The exceptions from the general case are that a higher portion of MOs were started on the planned start date resulting in that the average planned waiting time to start production was lower, 0,76 days. The waiting time from actual to planned finish date was in average 1,27 days which is higher than the general case. This means that the production lead time data on average is 1,99 days too long. The result of stratifying on Movex production lead times was that MOs that had a production lead time of two or three days was most often started on the planned start date. For MOs that had a production lead time of four or five days the average time from planned to actual start date was large, over two days. The time from actual to planned finish date was also large. The actual production time for these MOs was however widely spread. This means that the production lead time is incorrect for some of the MOs that have a longer production lead time, but not for all of them.

Selection work center C10

This work center stands for 54% of all MOs. MOs that have been produced in the C10 work center has an average of 0,94 days from planned to actual start date. As with the general case, the variability of the average value per week is small. The production lead time is two days for all products in the C10 work center. The actual production time has also been studied in comparison to this, it showed that production was most often started and finished on the same day. The time from actual to planned finish date was 0,34 days. The production lead time is on average 1,27 days too long as can be seen in Figure 5-25.

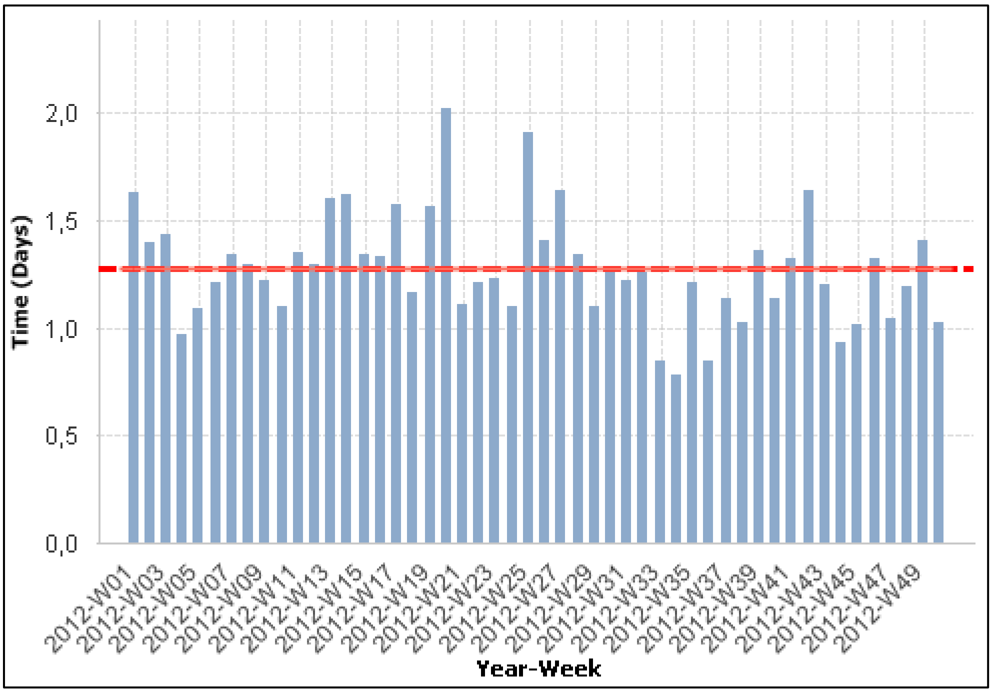

Figure 5-25: Average difference in planned and actual production lead time in days per MO per week for C10.

When examining the distribution of values in Figure 5-26 it is evident that most MOs have one day too long production lead time.

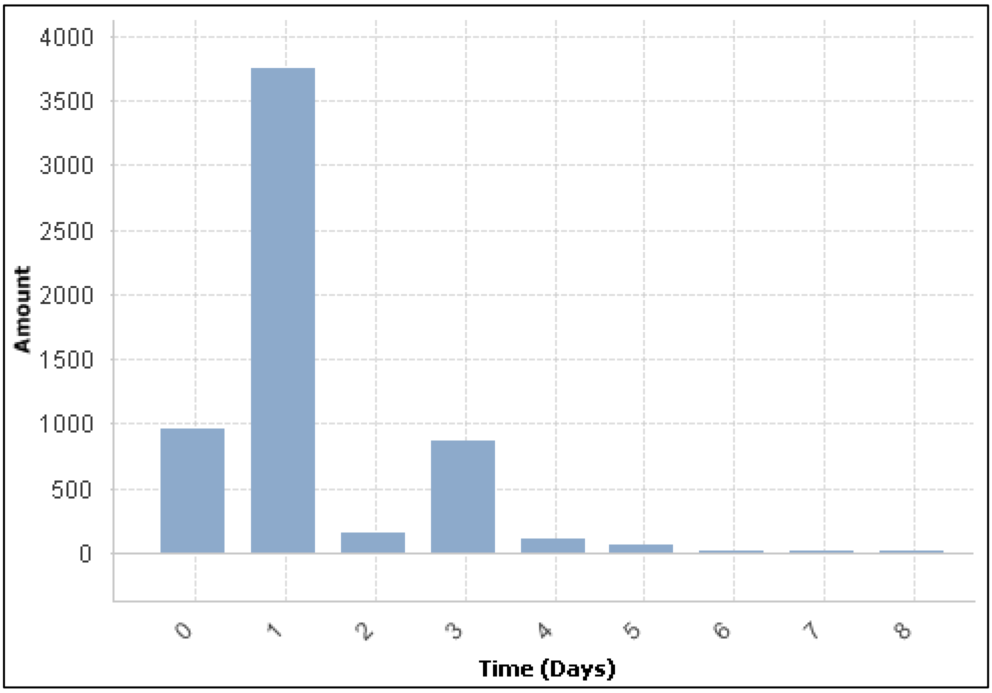

Figure 5-26: Distribution of difference in planned and actual production lead time in days rounded to integer for C10.

The boxplot in Figure 5-27 shows that there is some variability in the average values, but the outliers are quite low.

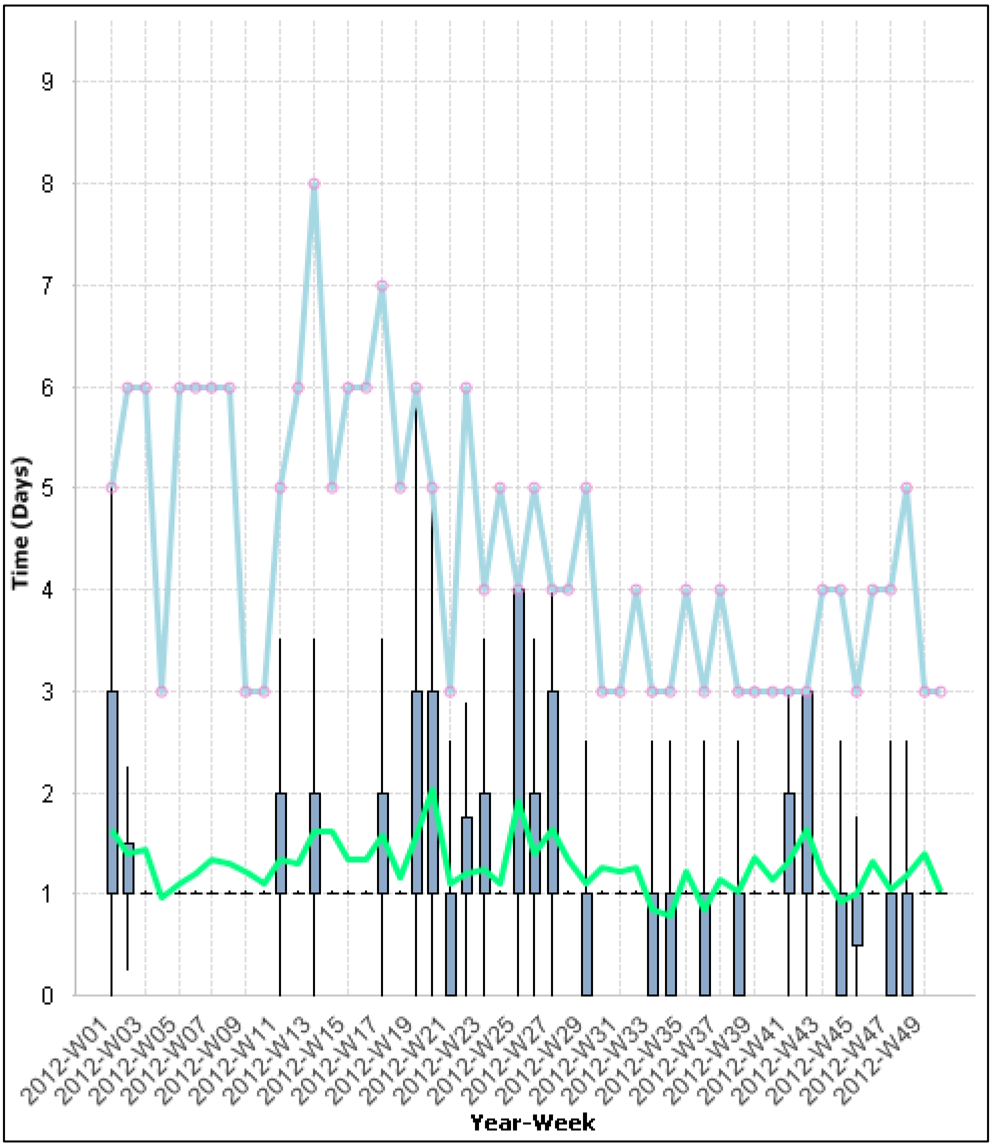

Figure 5-27: Boxplot of difference in planned and actual production lead time in days per week for C10.

Selection work center R10

When selecting the R10 work center 3% of all MOs are represented, this is because it is quite uncommon to roughen gaskets, for this reason the graphs will not give a fair representation and will therefore not be included in the report. The average planned waiting time to start production is 1,8 days. The production lead time is three days for all products in the R10 work center, but when examining the actual production time (reported in Movex) it is evident that production is always finished on the same day as it starts. This is because of MOs in the R10 work center are not reported as started until they are actually finished. The reason for this is that scrapping is common in this operation and the amount of used gaskets is not reported until it is known how many gaskets that was needed. The waiting time from actual to planned finish date is on average 1,24 days. Interviews with production planners as well as production personnel have revealed that R10 production in reality finishes on the same day as it starts in most cases.

Summary

As it is hard to make any general conclusions for MOs in the X10 work center, general changes to the production lead time will be impossible to do. In the C10 work center production is often started (and finished) on the second day of production. The MOs which were started on the planned start date were often finished the same day, meaning that there is an extra waiting day left after production. This means that one internal lead time day could potentially be removed from products in the C10 work center. As production in the R10 work center takes approximately one day and there are three days production lead time in Movex, two internal lead time days could potentially be removed here. When assessing the relative high risk of damaging the gaskets during roughening, which potentially could increase the production time, reducing the production lead time for products in the R10 work center with one day could be reasonable.

6 Improvement proposals

In this chapter concrete suggestions of improvements will be made based on the analysis.

6.1 Introduction

The analysis showed that the waiting time to start when material was available was the largest part of the lead time within the scope of the project. After analyzing the measurement further it was then determined that this waiting time could be divided into two separate waiting times. Analysis of the first part, planned waiting time to start production, revealed that the origin of this waiting time was due to lack of capacity in production. Analysis of the second part, difference in planned and actual production time, in turn revealed that the production lead time data in Movex is inaccurate. Proposals on how to reduce these waiting times and thus reducing the overall lead time will therefore be made.

6.2 Increase production capacity and flexibility

It has been concluded that the main reason for the planned waiting time to start production was due to lack of capacity in production. The solution is therefore to increase the capacity and flexibility in production to be able to handle high (as well as low) demand. The production includes a lot of manual labor and therefore it is possible to increase capacity by increasing the amount of staff. It is not desirable to have a large amount of staff on site when demand is low and therefore the use of temporary staff is recommended. If ordinary employees would be used the flexibility would decrease. All necessary "infrastructure" needed to hire temporary staff is in place such as union agreements, companies that provide temporary staff etc. However, there is currently not enough available temporary staff to be able to release MOs to start production on the next day. When it is possible to obtain sufficient amount of temporary staff to the following day, the production planners should release orders to the next day if material is available, except for very large orders or surges in demand. This will in turn decrease the lead time with approximately 1,5-2 days.

As it will take time to make temporary staff available the full implementation of this will be left to Alfa Laval DC Lund, although a clear action plan will be created and the process will be initiated.

6.2.1 Action plan

1. Secure temporary staff that will be able to work with one days' notice.
2. Instruct the planners to release MOs to production after a maximum of two days (except for large orders or surges in demand) and instruct the production team leader to secure capacity for the adjacent days.
3. Evaluate if there is enough capacity with the temporary staff and that everything works as intended.
4. If there is not enough capacity available go back to step one, otherwise move on.
5. Instruct the planners to always release MOs to production the next day (except for large orders or surges in demand).
6. If there is not enough capacity available, secure more temporary staff until it is satisfactory.

If everything works as intended the planned waiting time to start production should now be approximately one day.

6.2.2 Potential risks and problems

One risk is that some days, temporary staff might not be available in the quantity needed to the next day. The solution to this is to have enough temporary staff available. The production could also be rescheduled if major surges in demand would occur. Because of these solutions the risks are small and can be dealt with.

6.2.3 Costs and benefits

The costs with this implementation will be the extra temporary staff which is hard to estimate. This will be left to human resources. Alfa Laval DC Lund will have to decide if the benefits are worth the cost.

The benefits of the implementation will be a reduction of 1,5-2 days in lead time. This in turn will increase customer service and therefore potentially the revenue as well, although this is also hard to estimate. A shorter lead time will also mean that the revenue will be received earlier. Based on data from 2012 the profit from return of investments of this would be in the region of 10 000 euro per year, when calculating with an interest rate of 8% (which has been determined by Alfa Laval).

6.3 Adjust production lead time data

The analysis of the waiting time from planned to actual start date showed that the production lead time data in Movex is incorrect for many products. As all products in the C10 and R10 work centers have too long production lead time in Movex compared to the time it actually takes to produce them, a direct reduction of production lead time could be done for these. As there is a large inconsistency of the accuracy of production lead time data for products in the X10 work center, general changes cannot be made to these products. These products will instead have to be corrected on a continuous basis. By improving the accuracy of the production lead time in Movex a reduction in lead time can be made. The reduction will come from both reducing the time from planned to actual start date as well as from reducing the time that products are finished too early, as seen in Figure 5-16.

6.3.1 Direct improvements

The production lead time data for products manufactured in the C10 and R10 work centers can be corrected directly. All products in C10 work center should be changed from two days to one. In R10 work center the production lead time should be changed from three days to one after consulting with management.

6.3.2 Continuous improvements

To be able to correct the production lead time data for products manufactured in the X10 work center a continuous improvement is suggested. A computer based tool could be created so that it on a daily basis was possible to analyze the production lead time for MOs that was finished on the previous day. The tool should in a clear way display which MOs that were finished earlier or later than planned. The person managing the tool should then discus these products with the team leader in production to see if the production lead time should be adjusted.

By continuously following up and adjusting the production lead times using such a tool just described will result in that the production lead time data in Movex eventually will be correct for all products.

6.3.3 Potential risks and problems

A potential risk with reducing the production lead time to one day is that MOs that are scheduled to be shipped with an early departure are finished too late. For this reason, data has been collected on which departures that are regularly used, see Figure 6-1. As can be seen, the most common departure is at 16.15, which is being used in approximately 36% of all shipments. The second most common departure is at 10.00, which is being used in approximately 23% of all shipments. After these, the departure at 12.30 is the most common, being used in approximately 17% of all shipments.

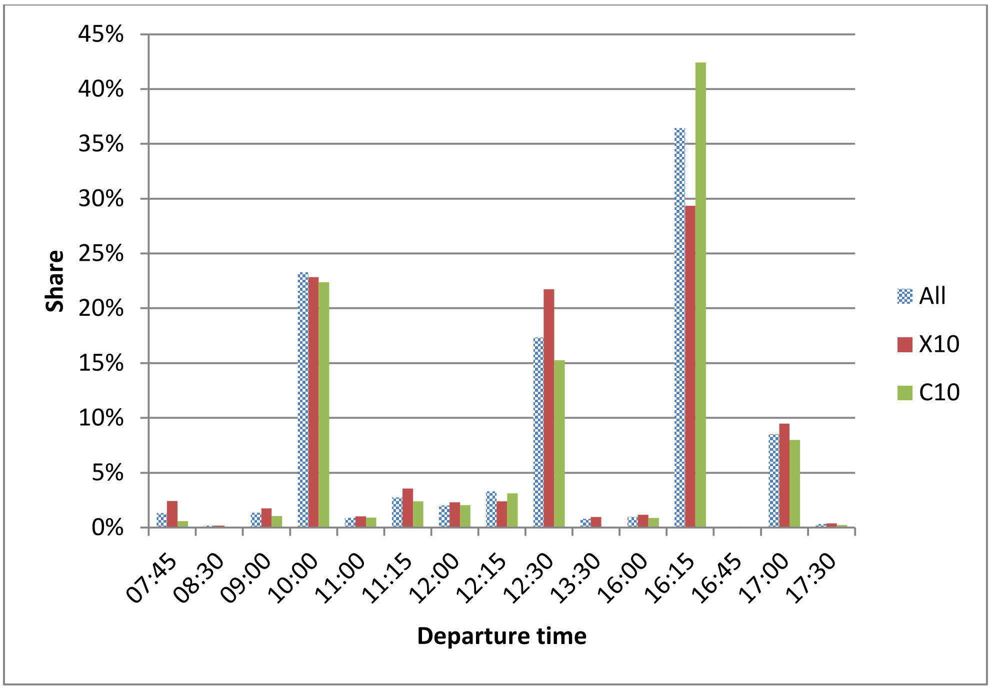

Figure 6-1: Route departures used for different work centers.

All routes that have departures at 07.45 have one internal lead time day in Movex, meaning that they need to be finished on the day before the departure. As the production personnel works from 07.00 to 15.45 (including lunch break), none of the departures should be a problem. At 10.00 the staff has already worked approximately one third of their day, so they should be able to complete all MOs that have a departure at that time.

At the moment some MOs are started on the planned start date as well as finished on the planned finish date in C10, meaning that they use two production days. Reducing the production lead time to one day could potentially be problematic for these products. However after analyzing these cases it has been concluded that the products in question take one day of production time. The reason that production sometimes use two days is because they can when they have spare time. This will not be a problem after the reduction of the production lead time as they will still be allowed to start production one day earlier. For this reason this should not be an issue when reducing the production lead time to one day in C10 work center.

One problem that has to be overcome when adjusting production lead times to be more accurate is for products that are made to stock (SI), especially when reducing the lead time to one day. This is because when products are made to stock Movex views them as available directly in the morning of the planned finish date. For this reason, the products with one production lead time day would have to be available directly when the production starts, which is impossible. However, this is already an issue as all stocked items has one less production day compared to the other products for this reason (which has not been compensated for). Management does however not want to increase the lead time for these items as the safety stock should cover this risk.

6.3.4 Costs and benefits

There is no large cost affiliated with this improvement suggestion. This is because the direct adjustments of the production lead time data for C10 and R10 products can be done in a fast, simple manner. The computer based tool for continuous improvement as well as instructing the person who will manage it will be done by the authors. It is estimated that the person managing the computer based tool will spend at most one hour per week in average the first 20 weeks after implementation and then practically no time in average.

Based on the sales data during 2012 the direct adjustment of the production lead time data would reduce the lead time with one day for 54% of the MOs and two days for 3%. Over time the waiting time between planned and actual start date as well as between actual and planned finish date should be reduced to almost zero from a total of 1,6 days. When CRD a.s.a.p. and material is available from CO entry date this reduction will represent a 30% decrease in internal lead time (keep in mind that the time from actual to planned finish date now is included in the internal lead time). When CRD a.s.a.p. and material is not available from CO entry date this reduction will represent a 10% decrease in internal lead time.

A reduced lead time to customers requesting delivery as soon as possible will result in earlier revenue. With the sales data for 2012, this results in approximately 9300 euros per year in missed profit from return of investment, when calculating with an interest rate of 8%. Reducing the lead time also results in less tied up capital, the time that products have been finished earlier than planned during 2012 has an alternative cost of 4300 euros per year when calculating with an interest rate of 12%. The reason for using a higher interest rate for the tied up capital is because of the cost and risks associated with having finished goods stored in the warehouse. This interest rate has also been determined by Alfa Laval.

7 Implementation

In this chapter the chosen implementations as well as how to implement and evaluate them will be presented.

7.1 What to implement

The main implementation will be adjustments of production lead time data in Movex as described in chapter 6.3 Adjust production lead time data. Both the direct adjustment of production lead time for C10 and R10 products as well as the continuous improvement for X10 products by using the computed based tool will be implemented.

Apart from the main implementation an initiation of the process to increase the capacity in production will be made, as mentioned in chapter 6.2 Increase production capacity and flexibility. To finalize the implementation the action plan will be left to Alfa Laval DC Lund.

7.2 How to implement

The data adjustment will be made in two steps. First of all the production lead time will be changed from two days to one day for all products in the C10 work center and from three days to one in the R10 work center. The final step is then to appoint a person that uses the computer based tool to analyze the production lead times and change them accordingly. This step will be a continuous process but with time it can be performed more seldom as the production lead times will become more accurate.

The initiation of the process that is going to yield more flexible capacity will be done by discussing with management and decide who will be responsible for this process. The unit manager for production will be responsible for securing temporary staff.

7.3 How to evaluate

The difference between planned and actual start date as well as planned and actual finish date will be measured. If these lead times decrease after implementation it should mean that the data on production lead times in Movex are becoming more accurate.

8 Results

In this chapter the results after the implementation will be presented.

The difference in planned and actual production lead time will be presented as a sum of the time between planned and actual start date and actual and planned finish date. The implementation was made in the end of week two 2013. As mentioned in chapter 5.7 the data extracted from Movex database is for 2012 and in this case also for the first weeks of 2013. Large outliers does not exist historically so this time period should therefore not be a problem.

General case

The general case for all workstations can be seen in Figure 8-1. Already in the week of implementation the lowest value since Movex was installed 2008 was noted. In week three a much lower value was noted and the weeks after have slightly higher values but still low in comparison.

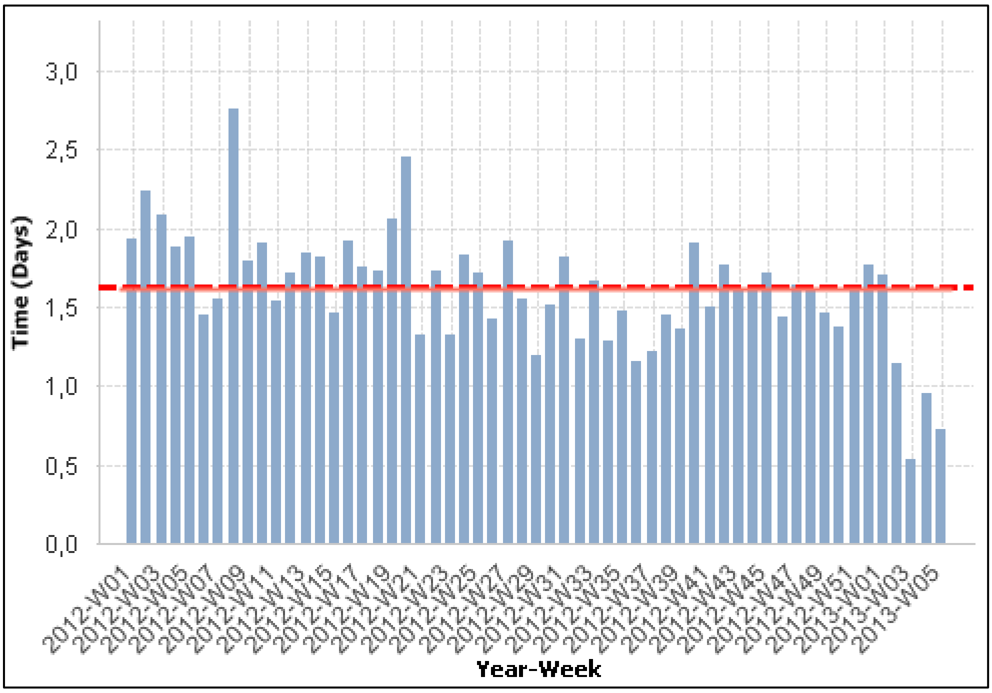

Figure 8-1: Average difference in planned and actual production lead time in days per MO per week for the general case.

Selection work center X10

The average difference in planned and actual production lead time in days per MO per week for the X10 work center can be seen in Figure 8-2. The lowest value ever was noted in week three and in the weeks after the average increased again. This is what is driving the increase for the same weeks in the general case. The reason that this has not decreased more is because of the continuous improvement. Due to this the decrease will be more visible at a later stage.

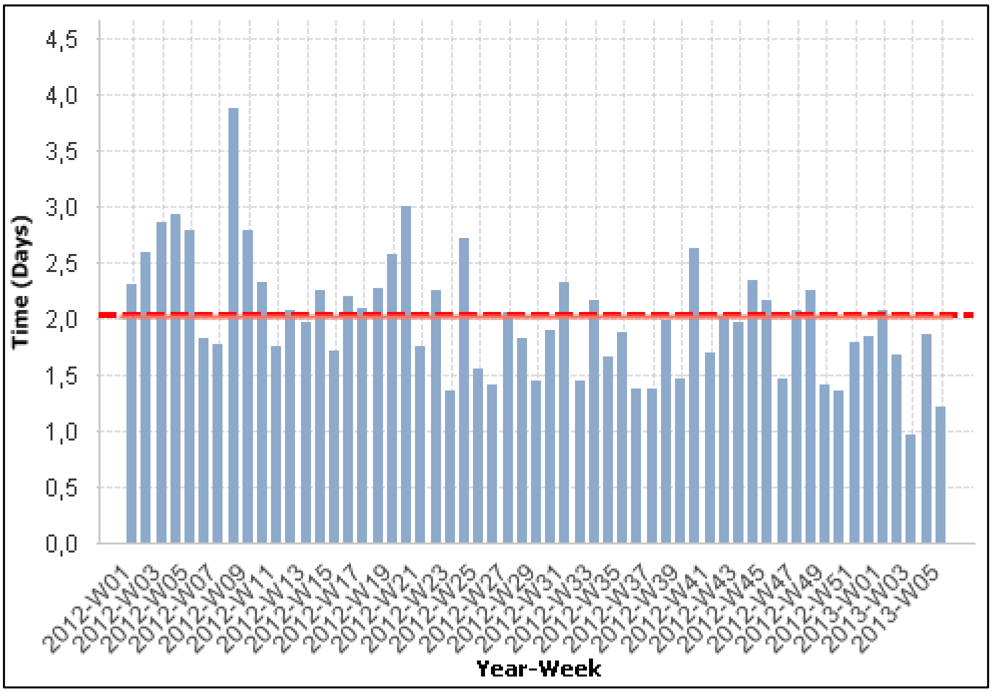

Figure 8-2: Average difference in planned and actual production lead time in days per MO per week for the X10 work center.

Selection work center R10

The improvements on R10 had effect week three as the lowest value ever noted can be seen this week in Figure 8-3. Note that no roughening was performed week five. Planners are sometimes manually overriding the production lead time and making it too long. If this was not the case the measurement would be zero as the production lead time is one day.

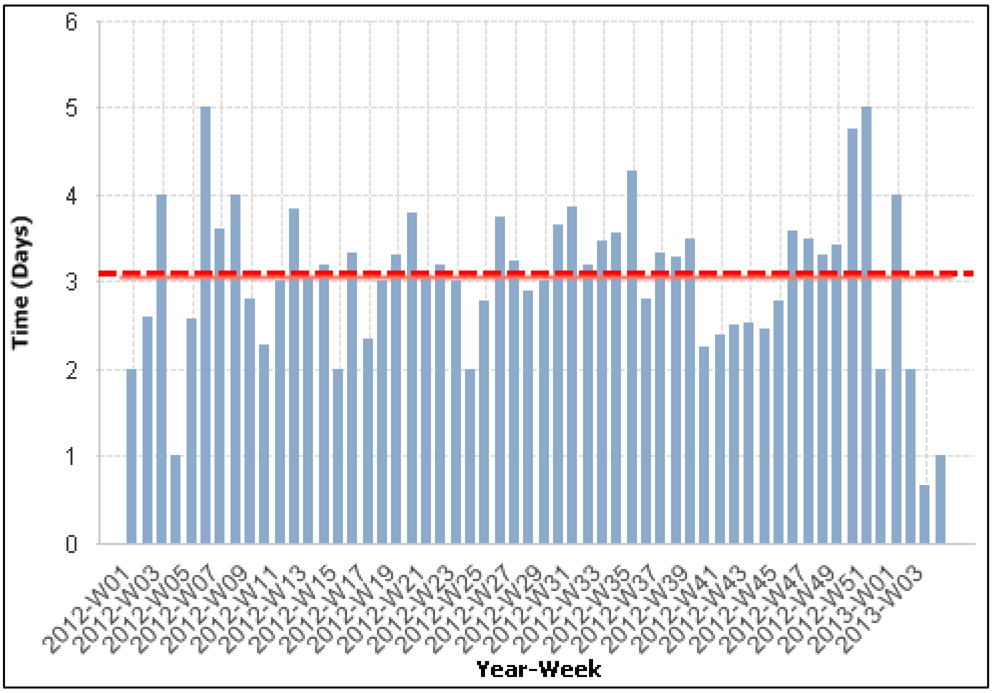

Figure 8-3: Average difference in planned and actual production lead time in days per MO per week for the R10 work center.

Selection work center C10

In week two, the same week as implementation, the lowest measurement ever was noted. The major decrease did however appear the week after that as can be seen in Figure 8-4. The last noted week has an even lower measurement. As in the R10 work center planners are sometimes overriding the production lead time otherwise this measurement would also be zero.

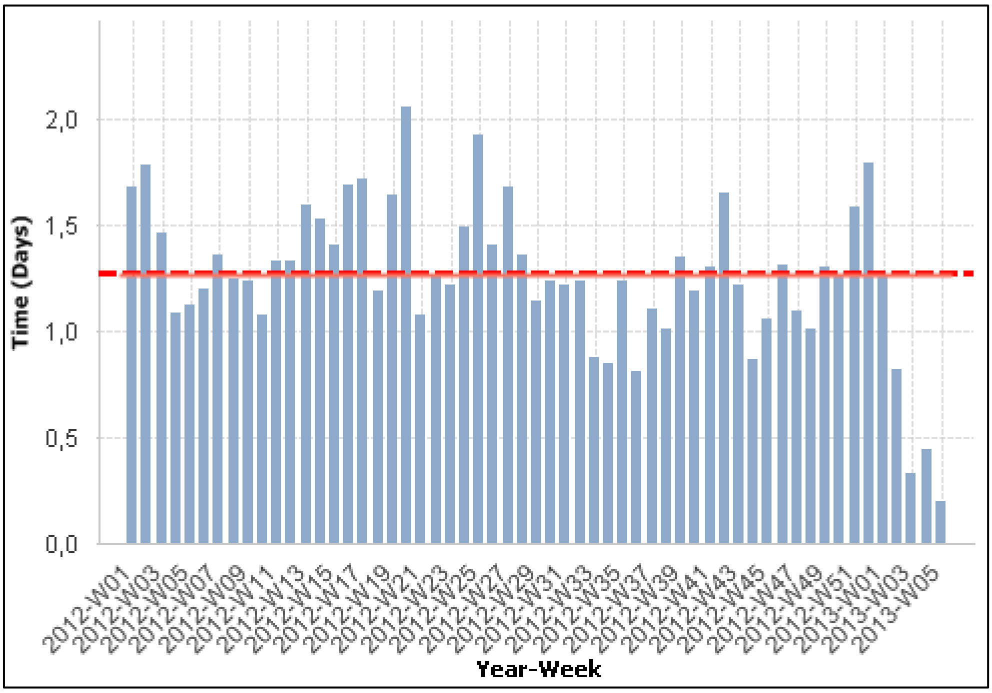

Figure 8-4: Average difference in planned and actual production lead time in days per MO per week for the C10 work center.

9 Conclusions and discussion

In this chapter conclusions from the research will be drawn as well as recommendations for further research. Scientific contributions of the research will also be presented.

The purpose of the research was to analyze the lead time at Alfa Laval DC Lund and the objective was to reduce it. The research has provided a thorough analysis which can be found in Appendix A: Lead time analysis and the result of the lead time reduction can be seen in chapter 8 Results. The implementation has worked as intended with a large initial decrease in lead time and the benefits mentioned in chapter 6 Improvement proposals is therefore expected to be fulfilled with time. The benefits will be a 30% decrease in internal lead time when material is available from start (CO entry date) and a 10% decrease in internal lead time when material is not available from start. This in turn will generate a total of approximately 14 000 euro per year in savings from less tied up capital and profits from earlier revenue. This means that the project deliverables has been achieved. Reducing the lead time results in less waste as well as the process becomes more JIT. For these reasons Alfa Laval DC Lund has taken a step towards becoming more lean.

The analysis has yielded information that Alfa Laval DC Lund can use to start other projects with the purpose to reduce lead time and/or improve their business. An example of this is the lead time from suppliers which is a large part of the lead time and has a high variability.

From the research, conclusions can also be drawn that human interference with the ERP system drives lead times which is an interesting discovery. The lead time is increased because planners cannot perform good enough estimations when overriding the ERP systems calculations. This is not due to lack of planning experience but rather because it is a difficult task to perform. For this reason it is important that the ERP system performs these calculations and has the correct data available to do so. This research also demonstrates the importance of working with the ERP system and using its features in a correct way instead of working beside and overriding it.

9.1 Scientific contributions

The results of this research are not generalizable, however this report provides a good methodology of how the lead time both efficiently and effectively can be analyzed and improved in businesses. If a project should be initiated with the intent to reduce lead time this is an efficient way of structuring the project.

To perform the analysis the lead time should be divided into different but not to small and detailed processes. This should be performed to provide an overview (graphical is preferred) of the lead time and yield areas that could be improved. These areas should then, if possible, be broken down into even smaller processes. A root cause analysis should then be performed in order to find a solution that reduces lead time.

If the lead time was divided into the smallest possible processes from the beginning it could be unnecessarily time consuming. This is due to the fact that it is not efficient to solve all problem areas at once. This does however depend on the specific case/situation. One instance where this could be used is if a project had the purpose only to highlight all problem areas so that other projects in turn could solve them.

9.2 Further research

In addition to the already proposed improvements further areas of research and improvements will be presented in this chapter. Researching these areas could be done in projects similar to this. These recommendations will make the business more efficient, but also more effective.

Supplier lead time

As the supplier lead time is the largest part of Alfa Laval DC Lund's lead time, this should be the highest priority to reduce by working with suppliers. The time it takes to receive delivery must be reduced as well as suppliers must be able to provide a correct delivery date and time. It is also important to correct the supplier lead time data in Movex. This can be done in a similar manner as the current continuous improvement of X10 production lead times is performed.

Transportation time

Another large part of the lead time is the transportation time to customers. This can in most cases be reduced, however the cost will increase. To be able to assess whether a shorter transportation time for a higher cost is desirable, Alfa Laval DC Lund needs to discuss this with their customers. It is also important to correct the transportation time data in Movex. This can be done in a similar manner as the current continuous improvement of X10 production lead times is performed.

Earlier MO release

When it is possible to release MOs to start production the next day Alfa Laval DC Lund should investigate if it is possible to release MOs to start production the same day. This will reduce the lead time further. However to be able to do this, as well as other improvements, the data resolution in Movex will have to be changed to date and time instead of just date as it is currently for some time values. This will also facilitate other areas such as analysis of lead time measurements as they will become more accurate.

Automated MO release

Another improvement that can be made when it is possible to release MOs to start production the next day is to create an automated release solution. This will reduce the lead time as well as that one extra person will be available to work in production which will increase the production capacity. Production planners will however still be needed to a small extent to reschedule MOs for example.

Dividing of work stations

To be able to analyze and manage the production in a more efficient way the production operations have to be divided in Movex, meaning that each operation should be reported when it is finished. The result of this is accurate operation times as well as waiting times between operations, which currently is unknown. With this information the lead time data can also be adjusted to fit reality.

Digitalize MO papers

When the production operations have been divided it is recommended that Alfa Laval DC Lund investigates the use of monitors at each work station. With monitors, all information needed or wanted by the operator can be displayed instantly. There would therefore be no need for printed pick lists or papers on MOs, and it can also improve the overview of the amount of MOs that are left to do. If an automated release solution also was in place, MOs released to production could instantly be transferred to the correct work station. This would decrease the lead time further.

Picking to production

It is recommended that Alfa Laval DC Lund examines whether the warehouse pickers should perform the picking to production. This is because the warehouse pickers have access to better equipment as well as that picking is their core competence. The forklifts used by warehouse pickers all have computers connected to Movex, which means that they receive live data on what needs to be picked. This means that pickers could receive a picking order so that material can be picked to production at the time when production needs the material (according to JIT theory). A kanban system could be used to prevent pickers from overflowing production. Although to be able to implement such a kanban system it is required that a time resolution of both date and time has been implemented as well as that the production operations have been divided in Movex. Pickers could potentially also put away MOs between operations as well as after production is finished.

Material allocation

Currently the product location in the warehouse where picking should be performed is predetermined days before picking is actually done. This is because of that the pick lists for MOs need to be manually printed, often one day or more before production is scheduled to start. However the same rules apply to all orders. This results in that orders that are arriving later but have an earlier departure are forced to be picked from less favorable locations. If each work station in the production would have access to monitors that could display pick lists, the product location would not have to be determined until picking should be done. The ordered quantity should still be reserved for the specific order, but this will give the pickers freedom to pick in a more efficient way.

MOs finished too early

During the analysis of the lead time it was found that MOs that have a realistic customer request date are finished long before they should depart. This result in a large amount of tied up capital as well as the risks in form of damage to finished products and customers canceling their order. Producing these MOs earlier may also unnecessary strain production. It is recommended that the root cause for this is analyzed and resolved.

Correcting Movex data

While navigating through Movex as well as while analyzing extracted data from Movex, it has become evident that the data often is inaccurate. Inaccurate data leads to inaccurate decision making, resulting in lost control of the system and eventually the business. It is therefore recommended that Alfa Laval DC Lund continuously work with correcting their data. This can be done in a similar manner as the current continuous improvement of X10 production lead times is performed.

Improving forecasting

Forecasting is currently made to decide which products that should be made to stock, but as mentioned above the data in Movex is unreliable. This in combination with observations indicating that forecasting is unreliable has raised suspicions that the forecasting can be improved. In order to make accurate forecasting it is important that the forecasting is based on a sufficient amount of data. For these reasons it is recommended that Alfa Laval DC Lund investigates on what data the forecasting is based on as well as if it is made on theoretically correct calculations. For theory on forecasting Sven Axsäter's Inventory Control (2006) could be studied.

Review of stocked items

If the production operations are divided into several work stations in Movex more data can be collected and analyzed on production lead times. This should in turn generate opportunities for improving the production time. If the production can become more agile, it will be less profitable to make to stock. Stocked finished products could therefore be removed from inventory and instead make room for components. By increasing both the amount and variety of components in stock Alfa Laval DC Lund will become less dependent on supplier lead times and can therefore reduce the lead time to customers.

Priority directions

There is currently no easy way of prioritizing which MOs that can be delayed if the production gets strained resulting in that one or several orders needs to be delayed. In these cases it is up to the production team leader to examine all remaining MOs and make a decision, sometimes resulting in negative reactions from management. It is therefore recommended that some sort of priority direction is created from management. This means that the production team leader would not have to make own priority decisions, only follow directives.

Divide large MOs

In the current setup, it is not possible to divide large MOs into several MOs. This means that very large MOs takes up all free capacity in some work stations, hindering other MOs from being produced. If large MOs could be divided into several smaller MOs, the production of these could be spread out over a longer time period and thus not strain the production. It would therefore be desirable to investigate the possibilities of achieving this.

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Appendix A: Lead time analysis

As mentioned in Data extraction period in chapter 4.2.4 Lead time the lead time data extracted is from week 30 in 2011 to week 30 in 2012.

Waiting time before release to production

General case

In this case no selection has been made which means that the whole population is used. The average time it takes to release an MO to production is 1,32 days. This measurement is precise down the one second. The average can be seen in Figure A-1 as the red dotted line. The process has a high variability.

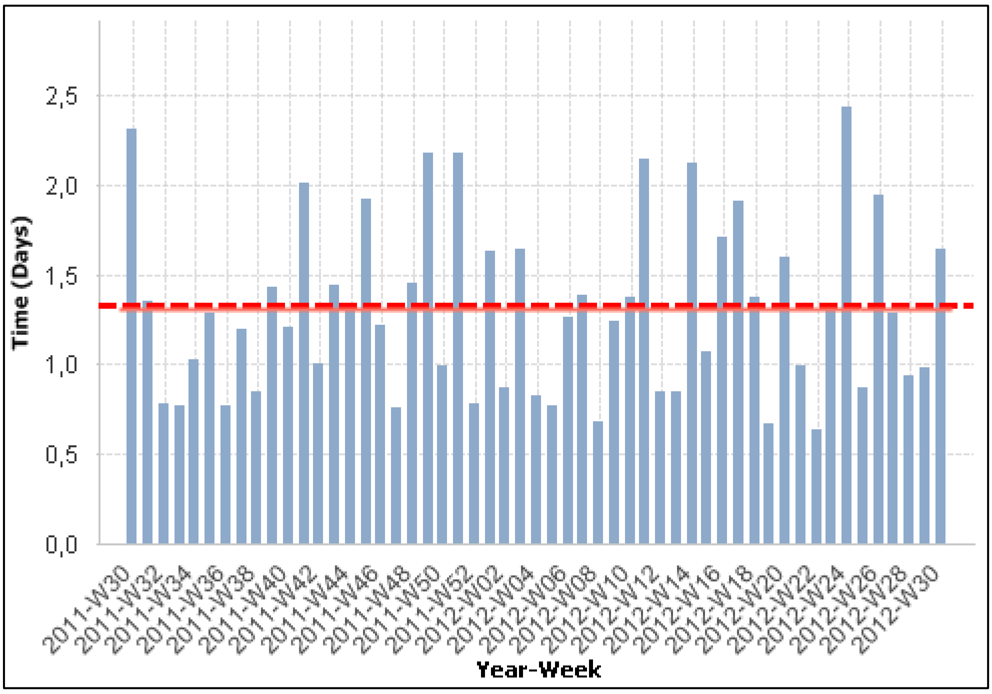

Figure A-1: Average amount of time in days per MO per week.

The distribution of the data is exponential and therefore the trend line is exponential as well. The most common time it takes to release an MO to production is 0-0,5 days as can be seen in Figure A-2.

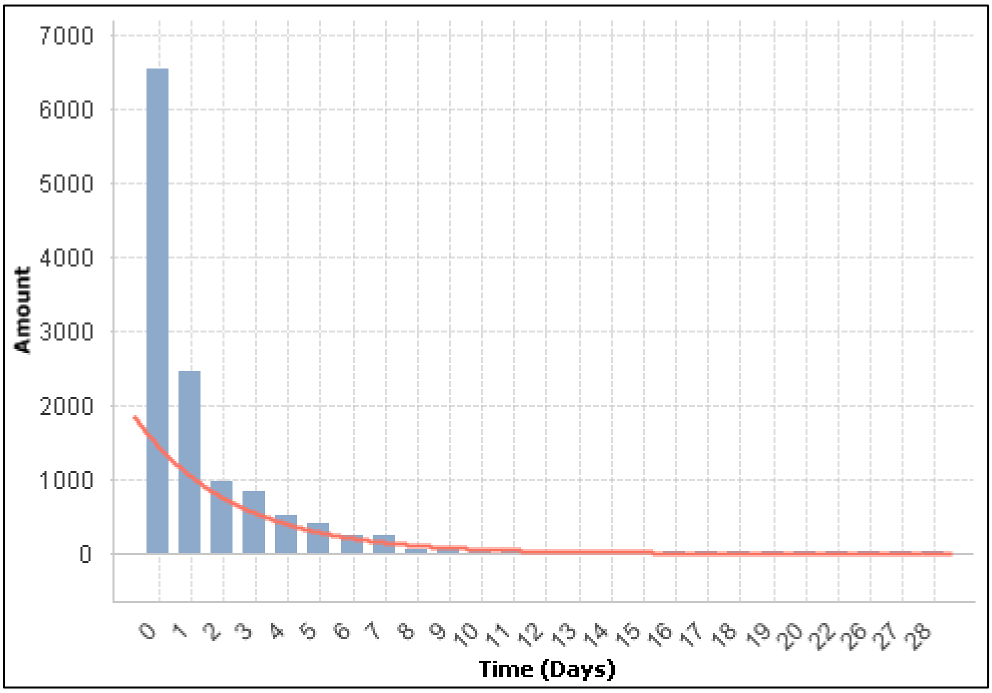

Figure A-2: Distribution of time in days rounded to integer.

When studying the boxplot in Figure A-3 it is evident that the largest values drive up the average because the average value in many cases is higher than the median as well as the median in many weeks are close to zero. During some weeks the distribution of values is spread out while in others they are denser.

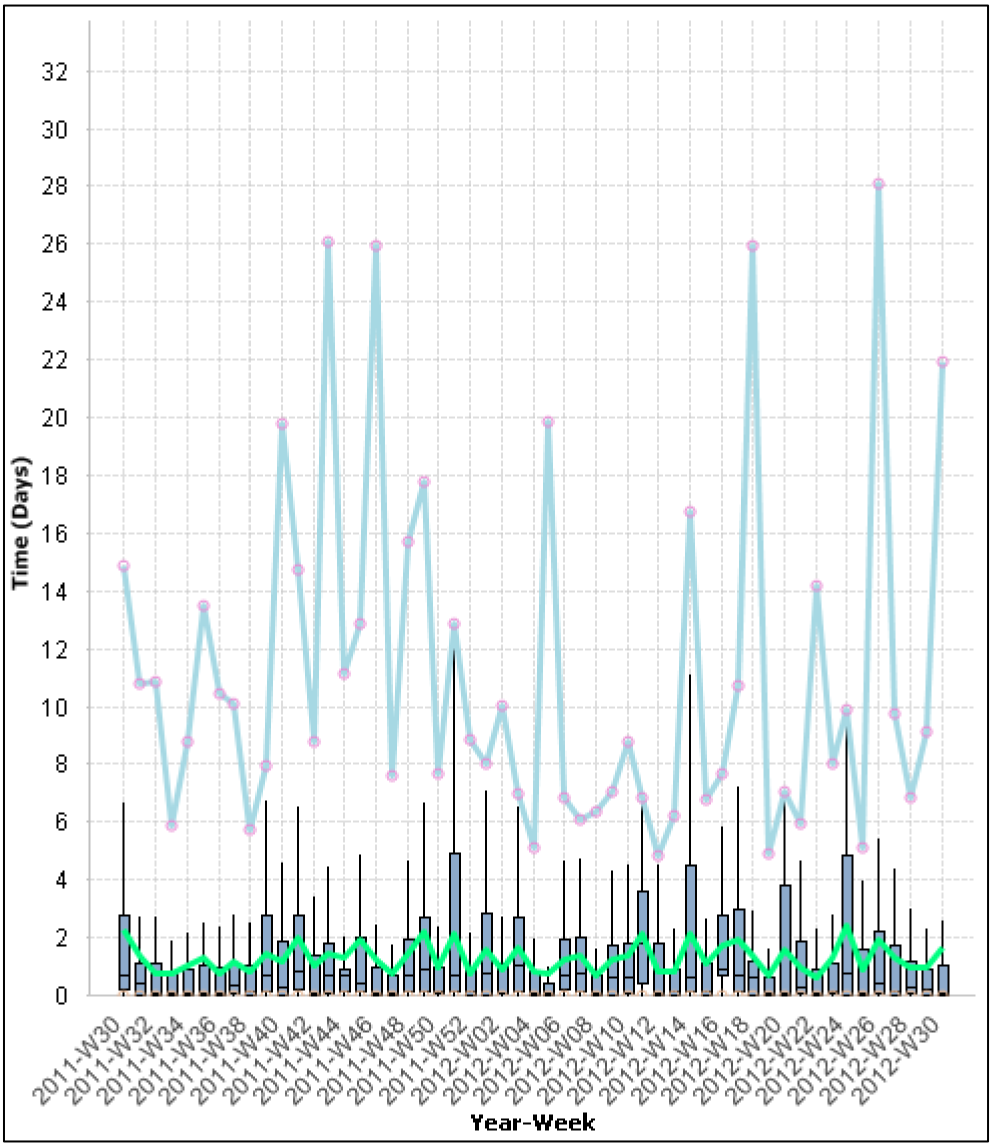

Figure A-3: Boxplot of time in days per week.

Selection material available

If material was available from CO entry date the average time it took to release MOs to production decreases to 0,39 days. This selection represents 46,0% of all MOs with a calculated material available date (as mentioned in chapter 5.5.1 Data validation). As can be seen in Figure A-4 the variability is high for the whole period except for the last weeks.

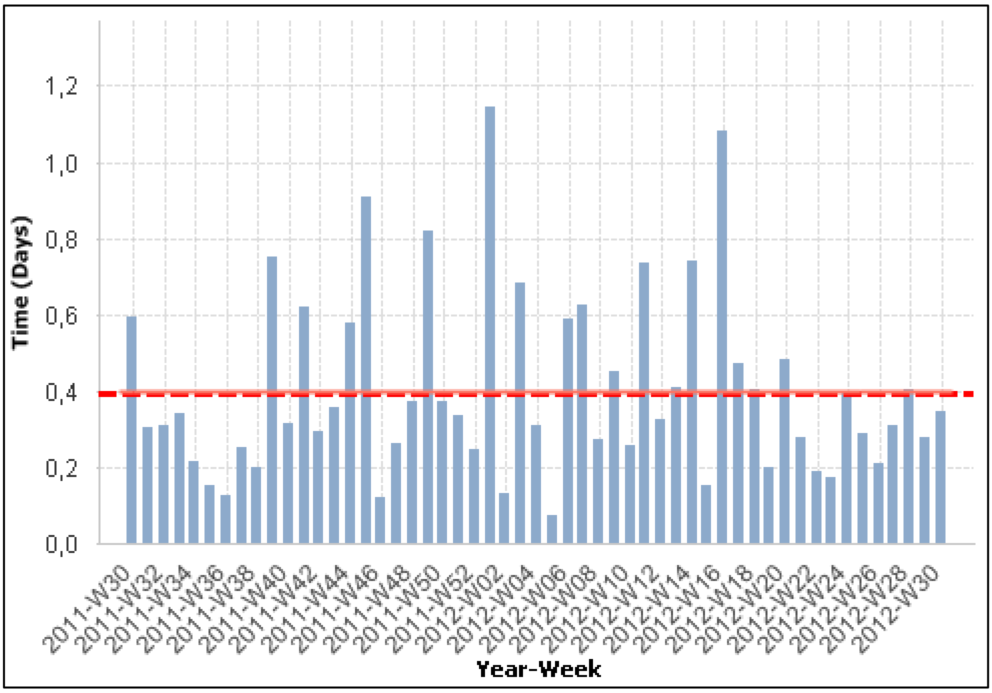

Figure A-4: Average amount of time in days per MO per week.

The distribution of the data is still exponential and the majority of time it takes to release an MO to production is also still 0-0,5 days as can be seen in Figure A-5.

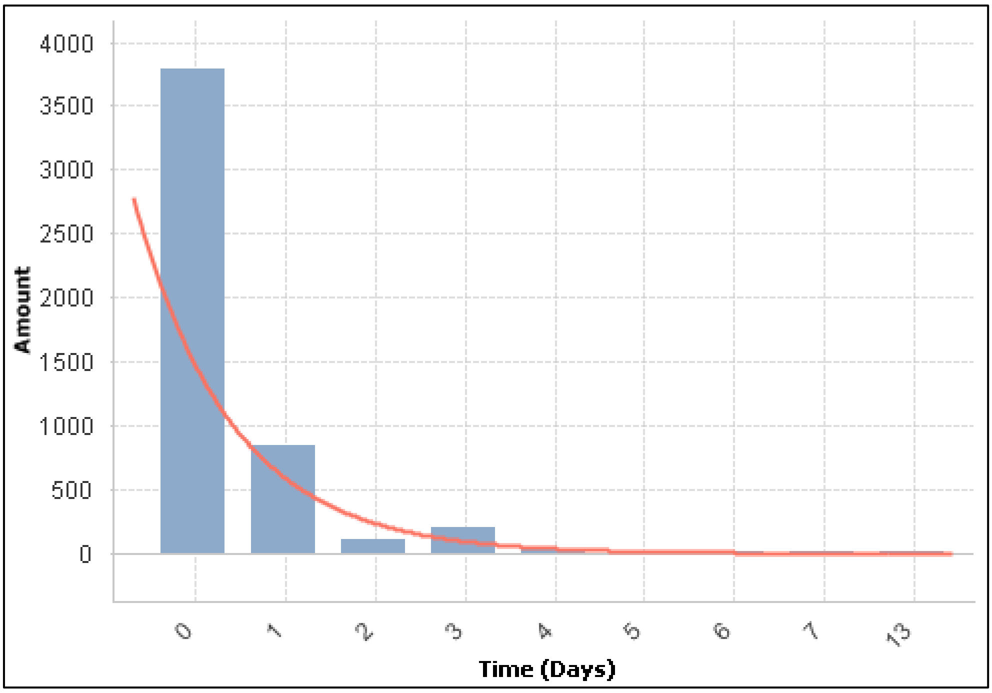

Figure A-5: Distribution of time in days rounded to integer.

Studying the boxplot in Figure A-6 for this selection it is even more evident that the largest values drive up the average. The distribution per week is denser, with much lower maximum values compared to the full population.

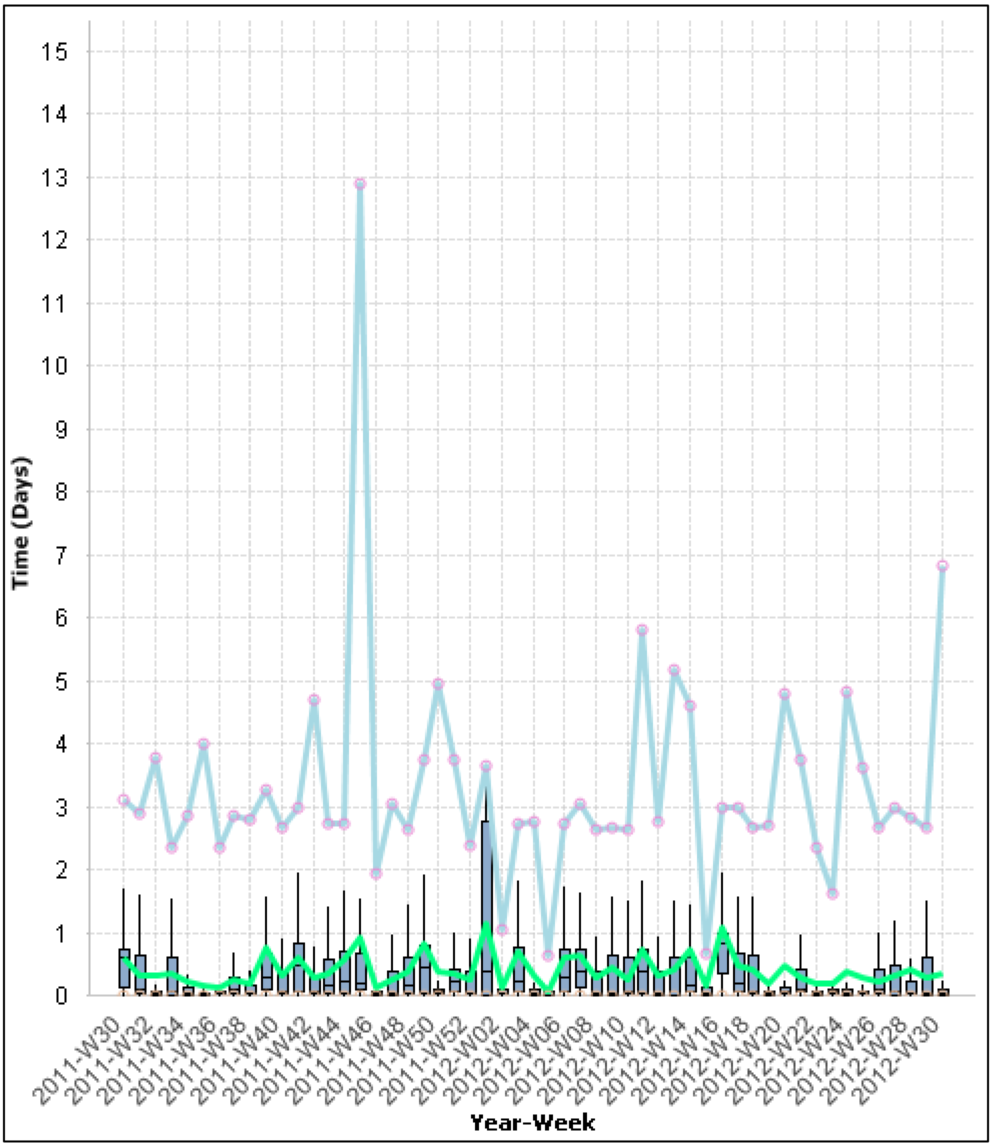

Figure A-6: Boxplot of time in days per week.

Selection material not available

When material was not available from CO entry date the average time it took to release MOs to production increased to 1,58 days. This selection represents 54,0% of all MOs with a calculated material available date. As can be seen in Figure A-7 the variability is still high.

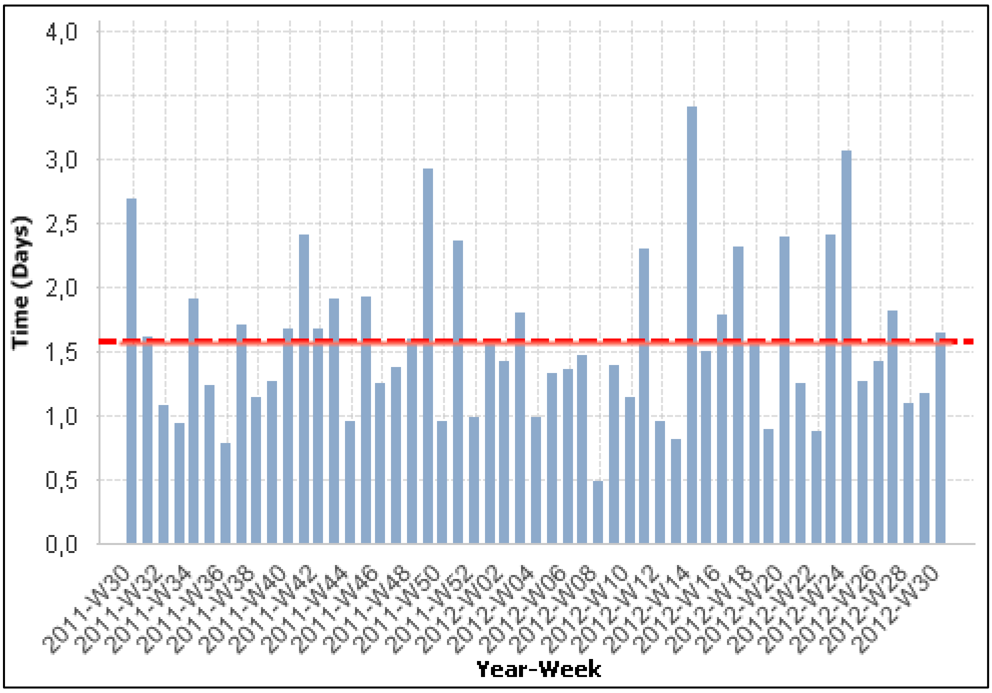

Figure A-7: Average amount of time in days per MO per week.

The distribution of the data is still exponential and the majority of time it takes to release an MO to production is also still 0-0,5 days as can be seen in Figure A-8. In this graph the exponential trend line is better fitted to the distribution then before.

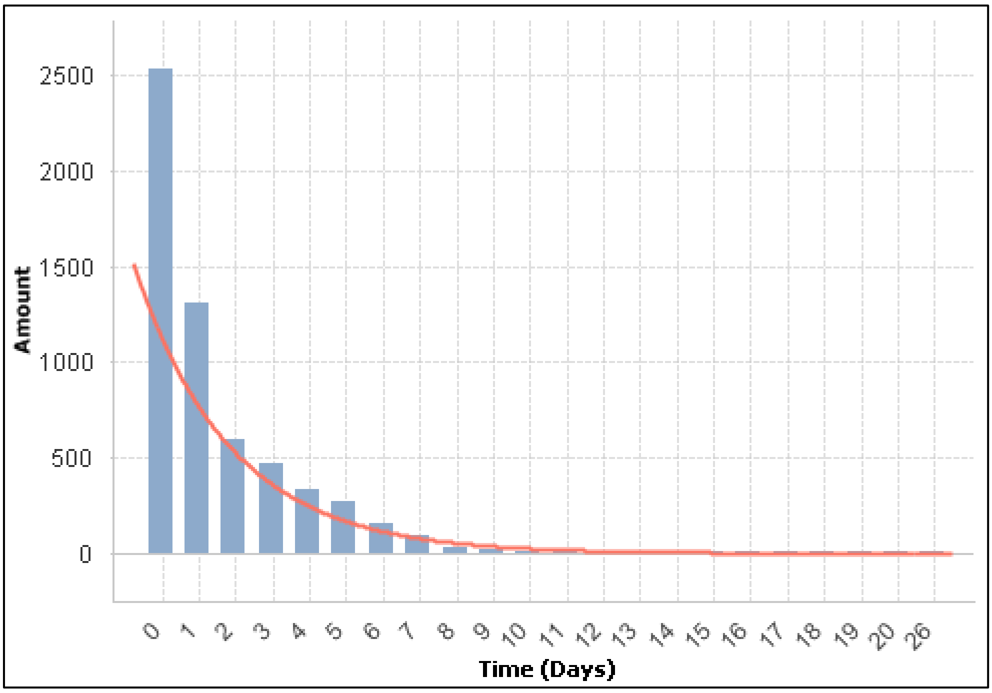

Figure A-8: Distribution of time in days rounded to integer.

The boxplot for this selection, Figure A-9, shows that the median values are closer to one day instead of the previously zero days. The average values are still higher than the median, although closer than before. The top whiskers are also closer to the maximum values, meaning that the values are more spread out. There is however some large maximum values between weeks 40-49 and 14-30.

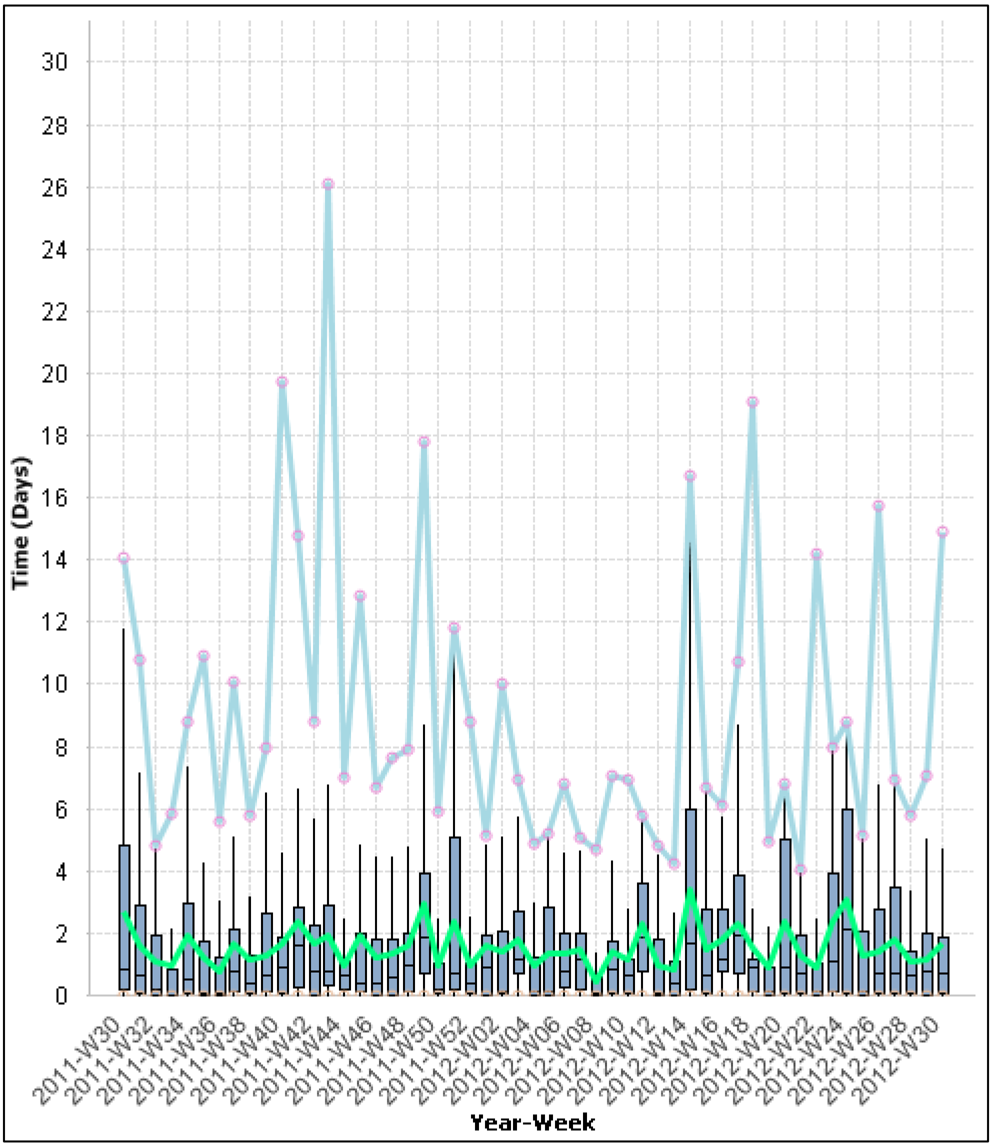

Figure A-9: Boxplot of time in days per week.

Selections based on CRD status

When making selections based on what CRD status MOs have, nothing specific of interest was revealed. No graphs of this will therefore be included in the report.

Waiting time for material to become available

General case

This measurement is by definition only interesting when material not is available from CO entry and CRD is as soon as possible. This is because when CRD is realistic purchasing will in some cases set a request date for material further ahead to reduce tied up capital. Therefore waiting time would be included in the measurement if CRD was realistic. For these reasons this selection has been made from the beginning which means that 39,9% of the MOs with calculated material date and a start date is shown. With this setup the average value (the red dotted line in Figure A-10) is 10,59 days. This measurement has a resolution of one second. In Figure A-10 it can be seen that the average per week has high variability. An interesting observation is that the measurement has an increasing trend.

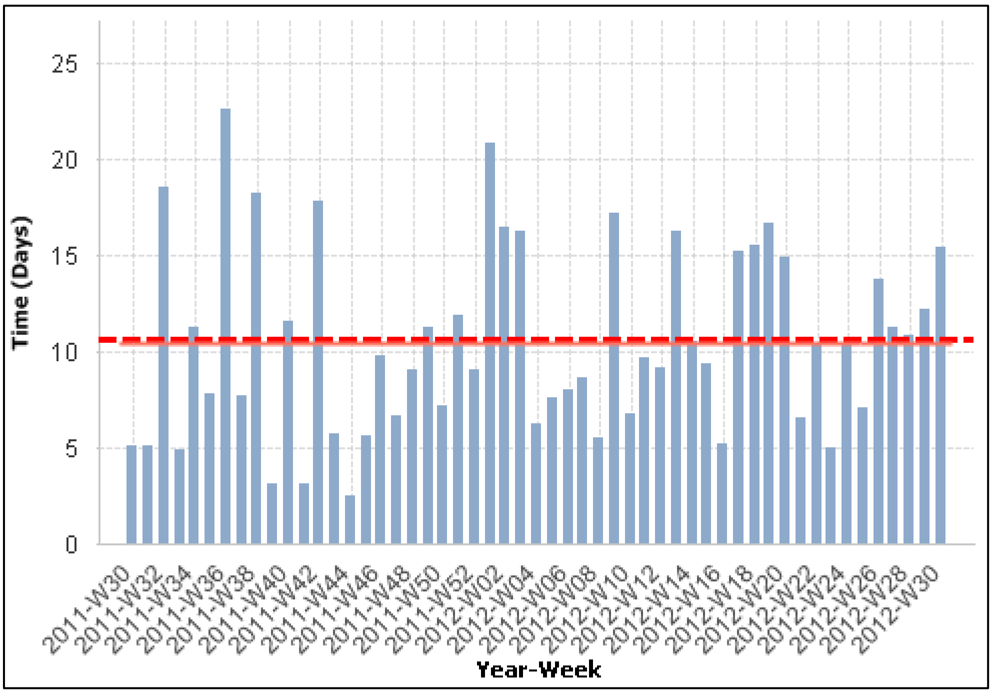

Figure A-10: Average amount of time in days per MO per week.

The distribution in Figure A-11 is exponential with some exceptions. The frequency of zero days for material to become available is high compared to other values. The tail of the distribution is long which indicates that there are many extreme values.

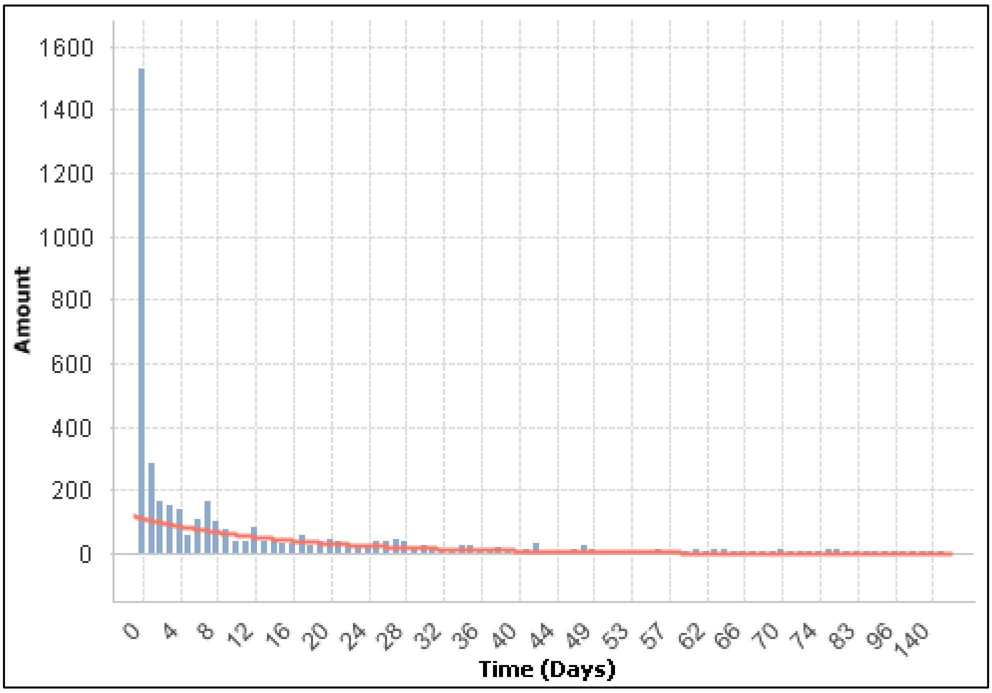

Figure A-11: Distribution of time in days rounded to integer.

It is also evident in the boxplot in Figure A-12 that there are high maximum values. The long tail in Figure A-11 can be seen in the boxplot as the boxes and whiskers are a large part of the span between the minimum and maximum values. This indicates that the process is unstable and therefore hard to predict.

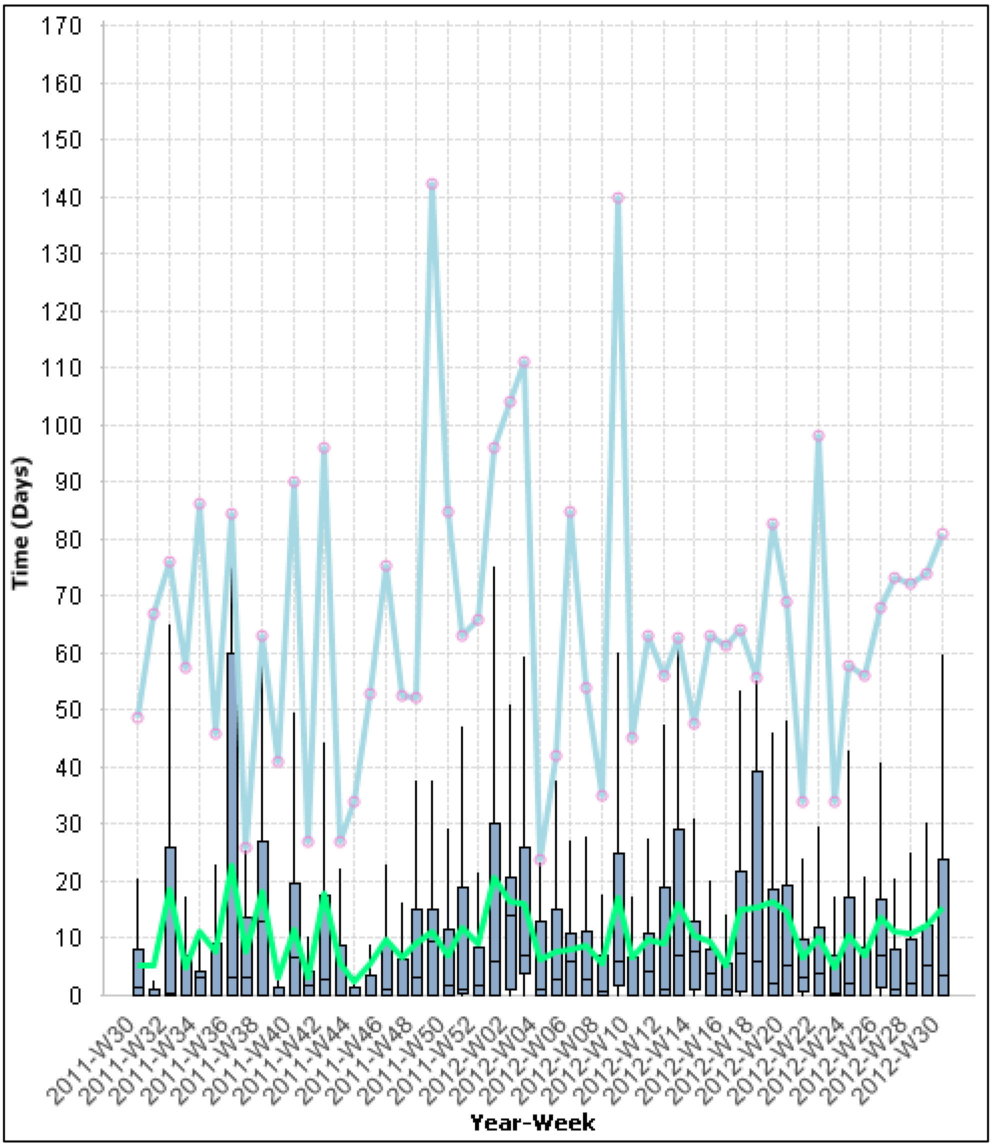

Figure A-12: Boxplot of time in days per week.

Waiting time to start when material is available

General case

For the general case for this measurement, the selection of data is all MOs that have a calculated material available date, an actual start date and CRD a.s.a.p. If CRD was realistic waiting time would be included in this measurement. With this selection 84,0% of MOs are represented. The measurement has been made on a daily basis. The average waiting time for a MO in this selection, from the moment that all MOs on a CO were available until production was started, was 4,12 days.

The average waiting time per week can be seen in Figure A-13. The variability per week is higher in the beginning but all in all it is low.

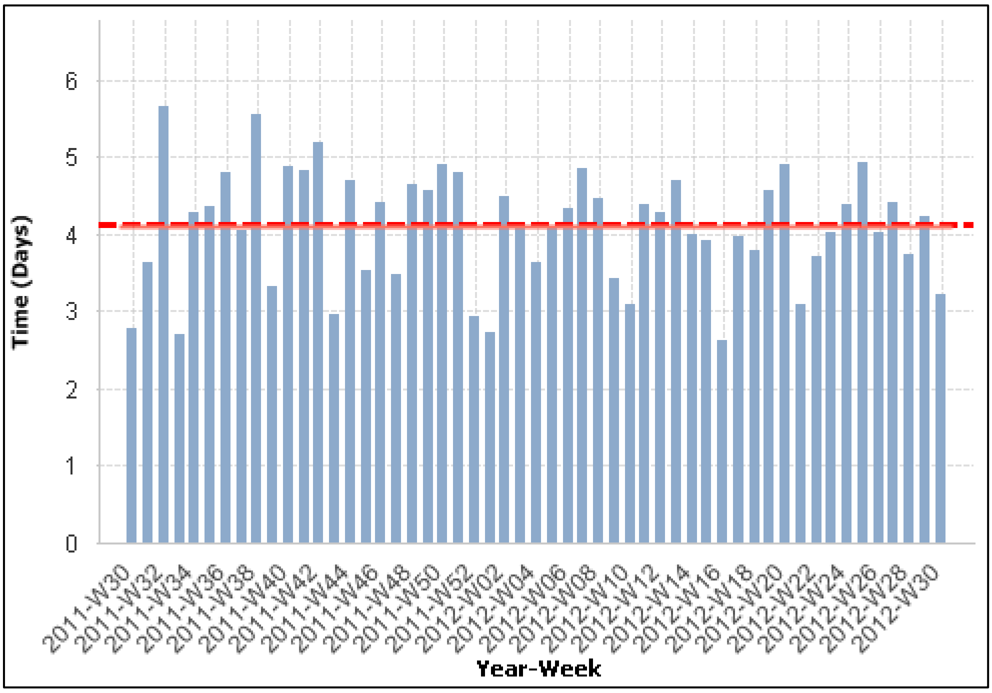

Figure A-13: Average amount of time in days per MO per week.

When examining the distribution of waiting time in Figure A-14, it does not correlate to an exponential distribution that can be seen in comparison with the trend line. The most common waiting time is one day followed by two days. Although from nine days and more the trend line seems to fit the distribution.

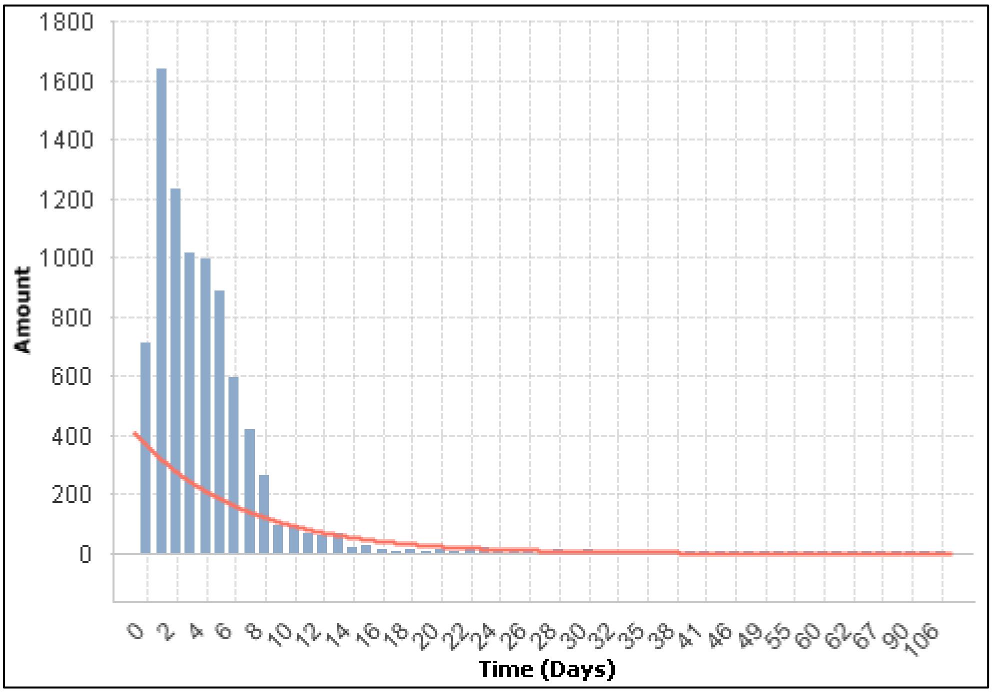

Figure A-14: Distribution of time in days rounded to integer.

When studying the boxplot in Figure A-15 it is also apparent that the majority of waiting time seems to be located between one and seven days. The maximum values are very high but apart from them the process seems to be somewhat stable.

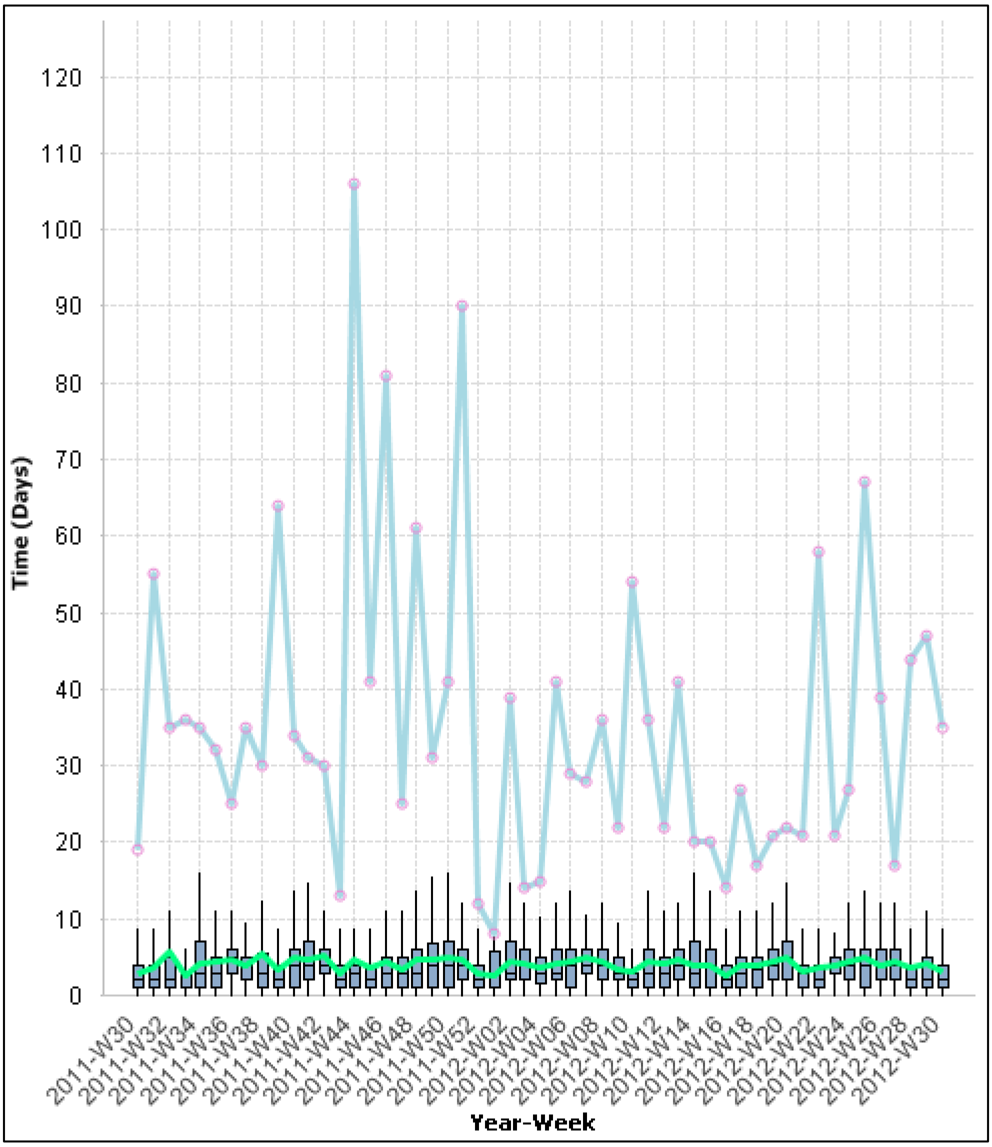

Figure A-15: Boxplot of time in days per week.

Selection material available and CRD a.s.a.p.

When material is available from CO entry date and customers request delivery as soon as possible, which is the case for 44,1% of the MOs, the average waiting time decreases to 3,32 days. The variability seems to increase for this specific selection compared to the general case, see Figure A-16. A small increasing trend can be spotted in the beginning of the period.

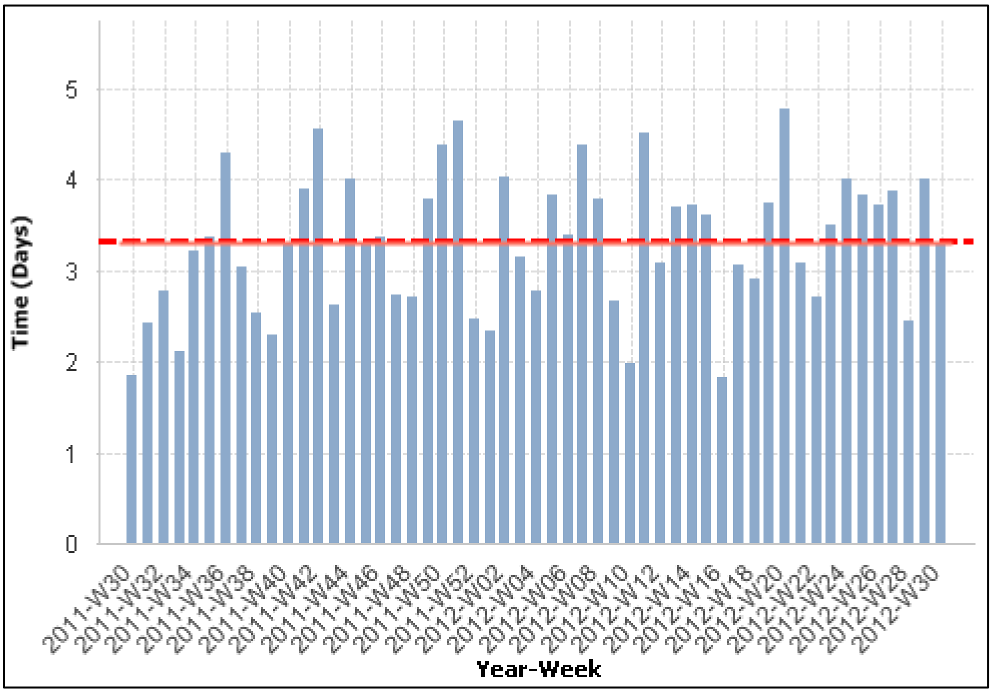

Figure A-16: Average amount of time in days per MO per week.

The distribution of days seem to be the same for this selection, Figure A-17, where the exponential distribution trend line still fits badly. The majority of values are still positioned at one day.

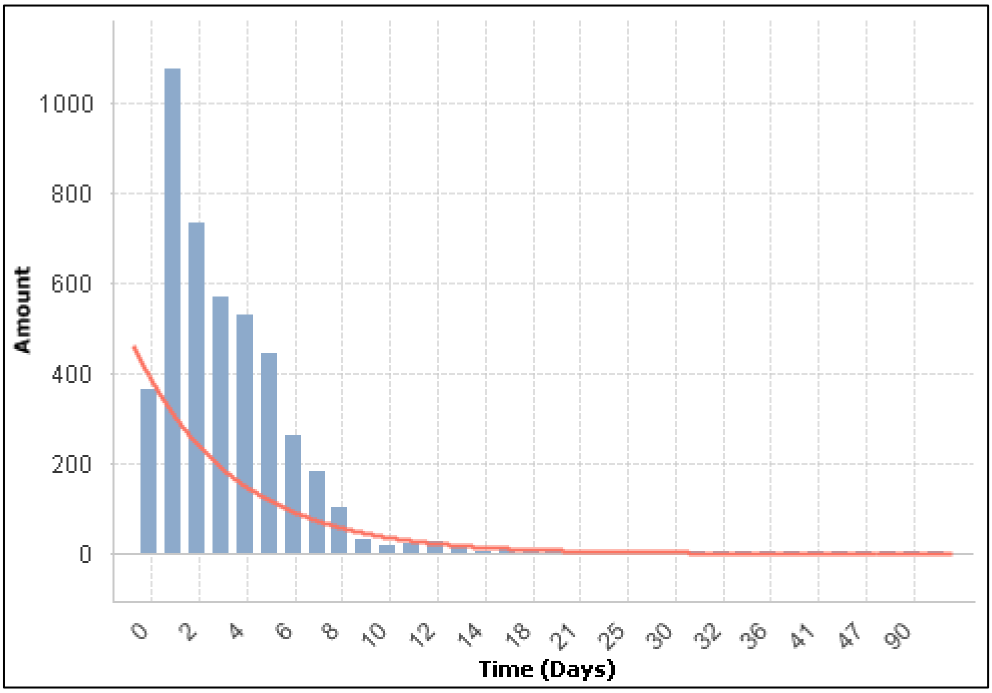

Figure A-17: Distribution of time in days rounded to integer.

The boxes in the boxplot, Figure A-18, seem to be slightly denser and the maximum values lower.

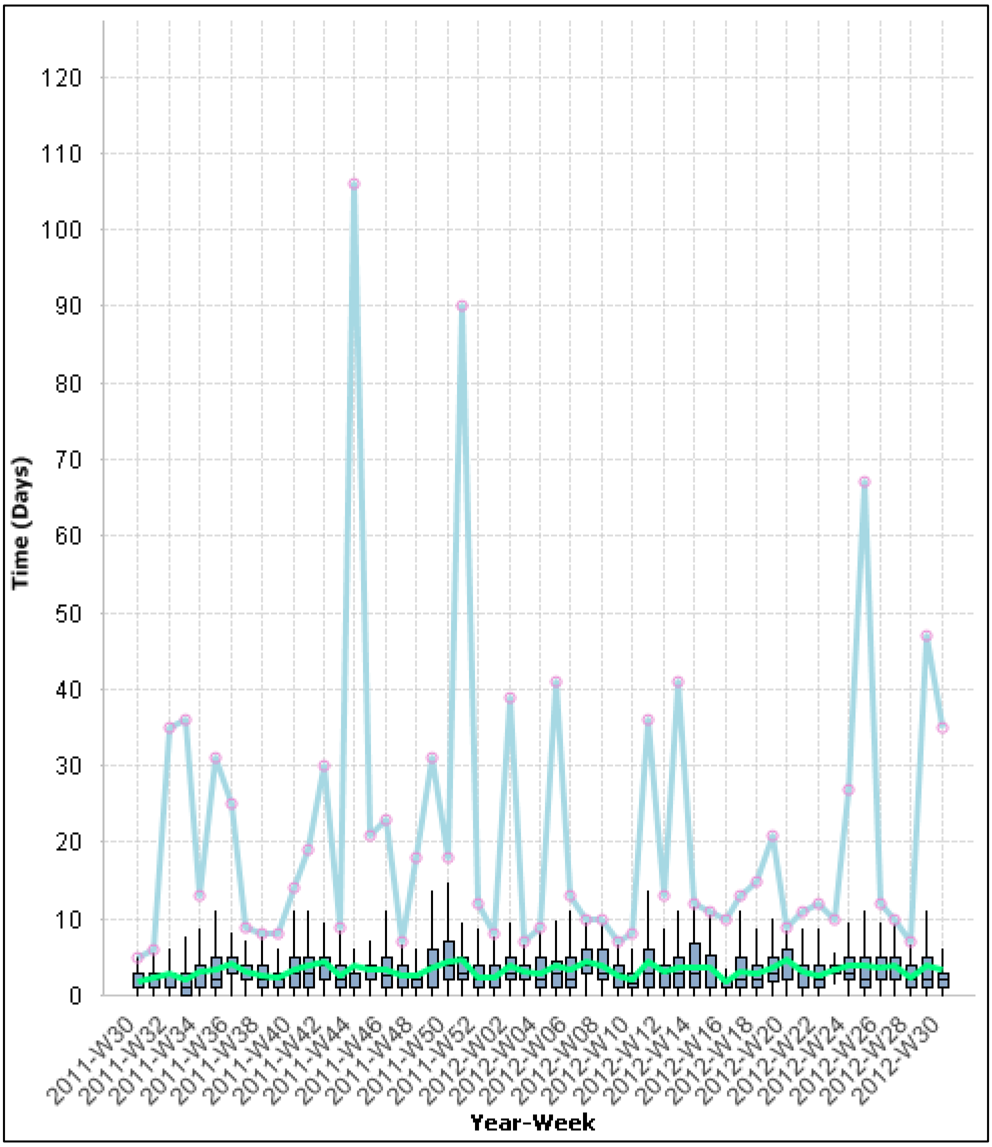

Figure A-18: Boxplot of time in days per week.

Selection material not available and CRD a.s.a.p.

When material is not available from CO entry date and customers request delivery as soon as possible, which is the case for 39,9% of the MOs, the average waiting time increases to 5,01 days which can be seen in Figure A-19. This means that after having waited for the suppliers to provide the material, production waits even longer to start producing after receiving material than they do if the material is available from start. This means that internally, on average, another 1,69 days are added to the lead time. The variability seems to decrease for the second half of the period.

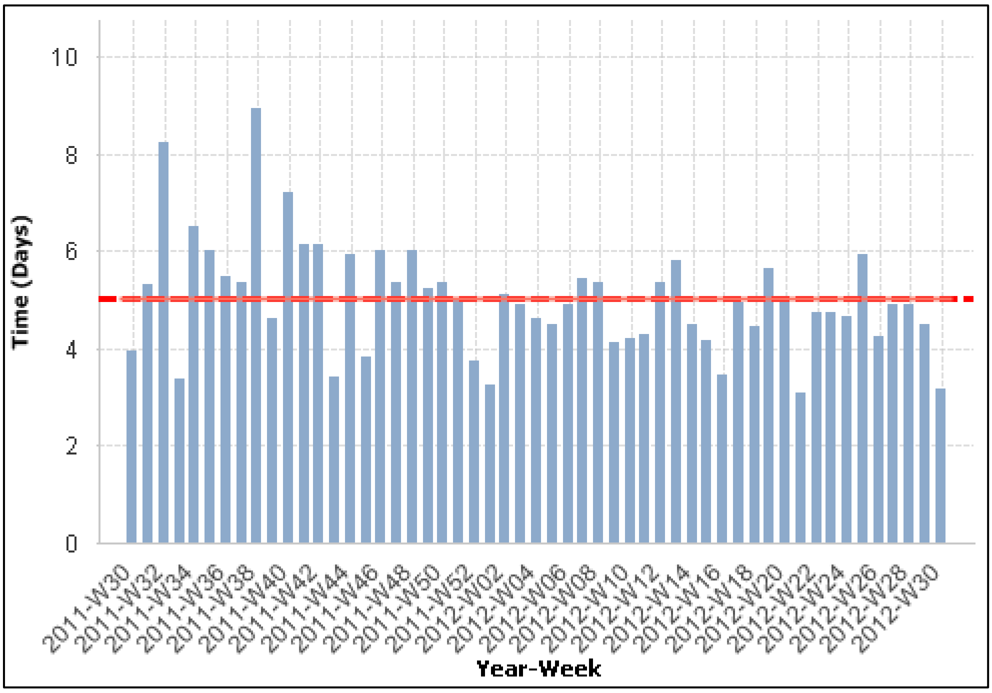

Figure A-19: Average amount of time in days per MO per week.

The distribution in Figure A-20 does not change much in form. The majority of values are still located between zero and eight days.

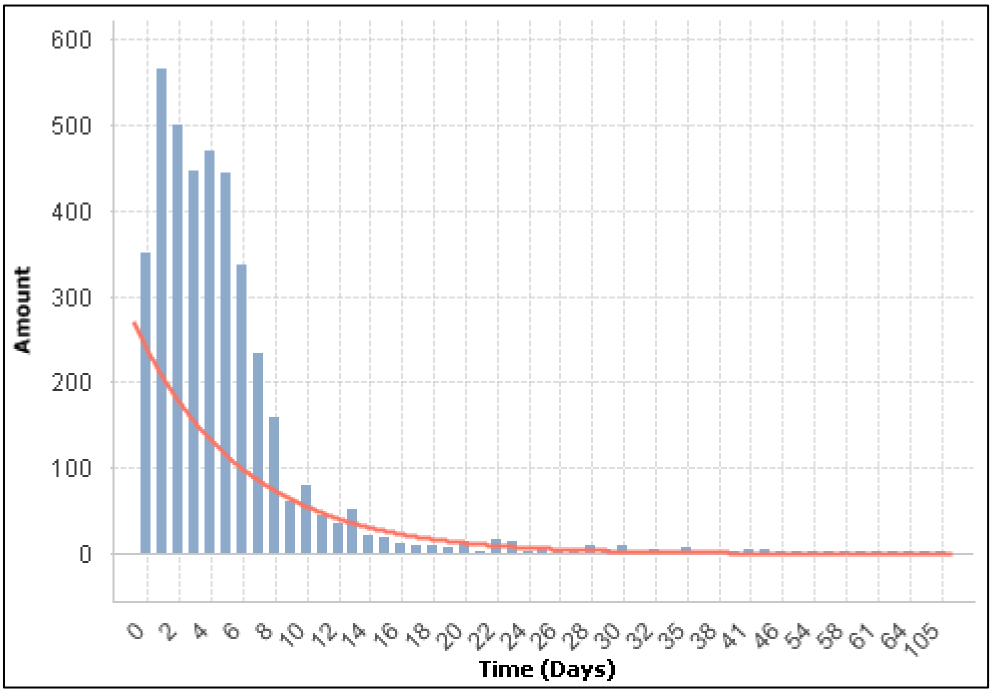

Figure A-20: Distribution of time in days rounded to integer.

The boxes in the boxplot in Figure A-21 are wider again and the maximum values are getting higher.

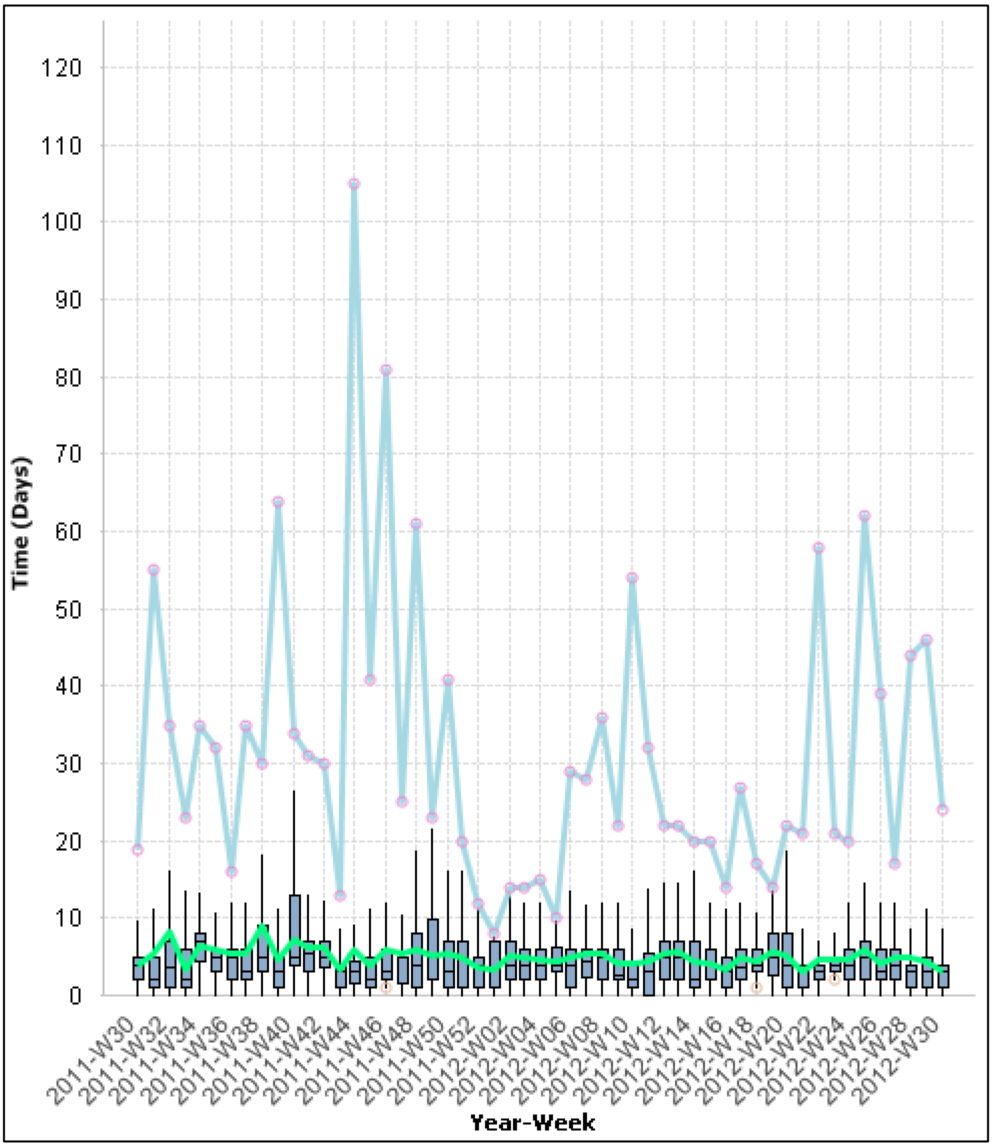

Figure A-21: Boxplot of time in days per week.

Selection material not available and realistic CRD

When material is not available from CO entry date and customers have a realistic request date, which is the case for 9,6% of the MOs, the average waiting time increases to 6,66 days. The variability also increases which can be seen in Figure A-22, but in the second half of the period it is lower than in the beginning. To receive material almost a week before doing anything value adding to it is not lean. It would be better to request a later delivery from the suppliers.

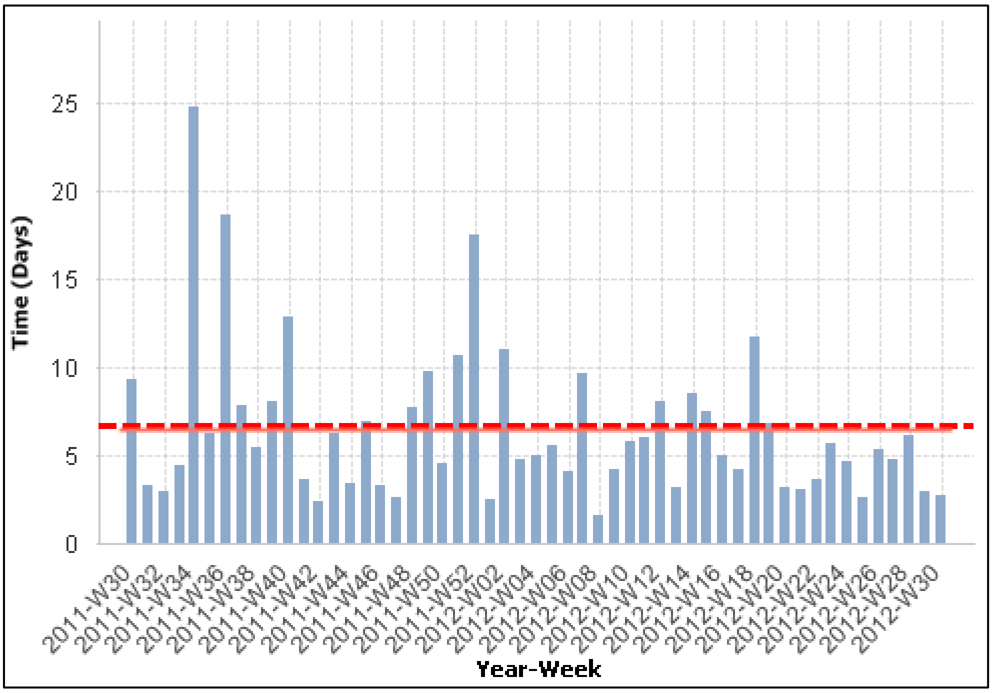

Figure A-22: Average amount of time in days per MO per week.

The distribution of waiting time can be seen in Figure A-23, the exponential distribution trend line does not fit well. The majority of values are between zero and eight days, where one, two and four are the most common.

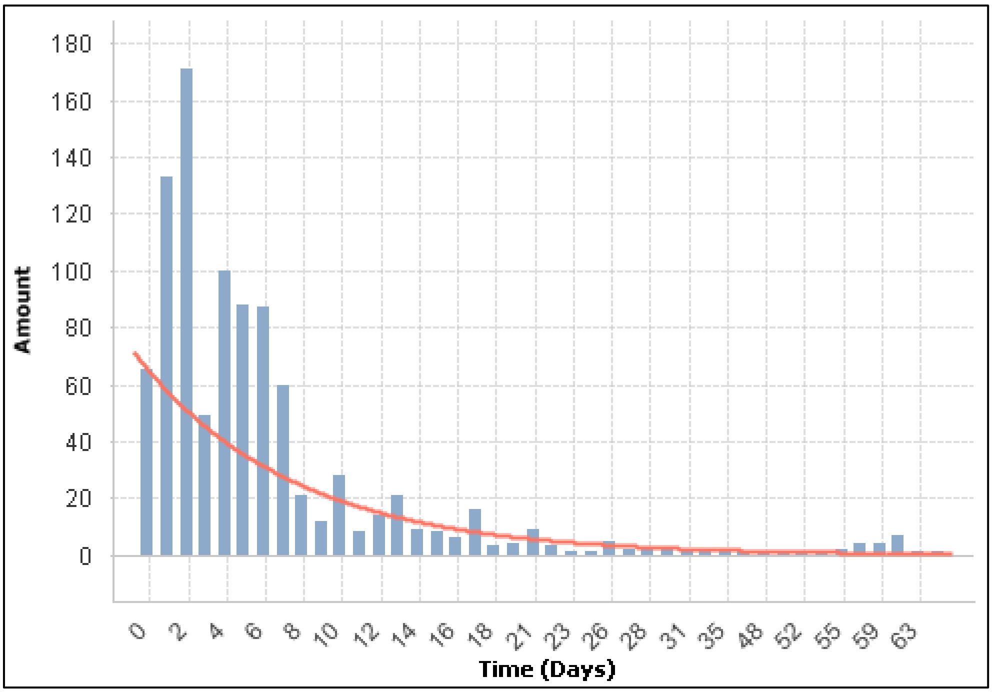

Figure A-23: Distribution of time in days rounded to integer.

The distribution per week, as can be seen in the boxplot in Figure A-24, is very shifting. The variability is large for the median, average and maximum values. This means that the process is unstable and therefore hard to predict.

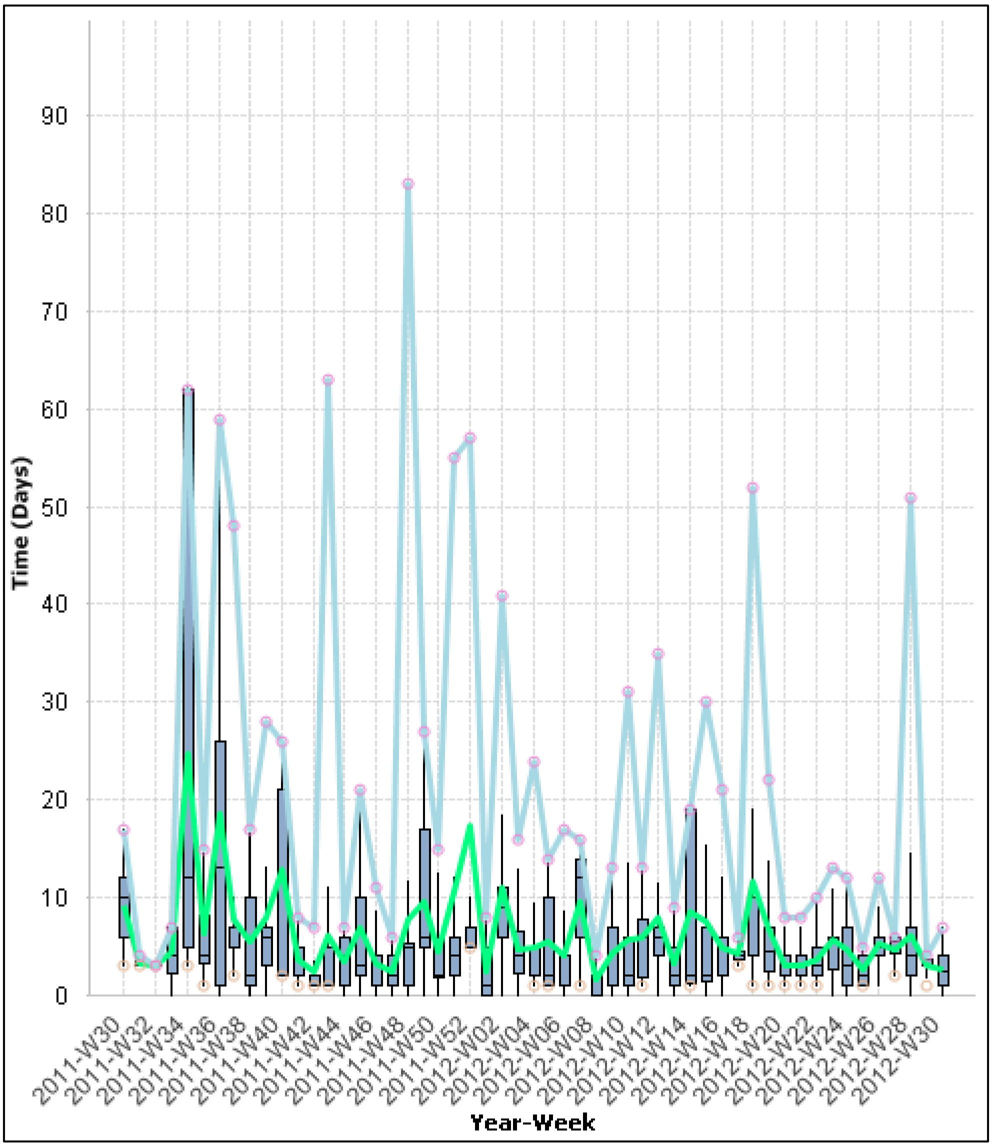

Figure A-24: Boxplot of time in days per week.

Selection material available and realistic CRD

There is no reason to examine this case as the waiting time is because of that the customer has requested delivery on a specific date. This means that it is better to have waiting time here rather than after production is finished. This is because as little value as possible should be added before it is necessary, meaning that production should be started as close to the customer requested delivery date as possible.

Total time from release to start

General case

In this measurement the selection that the customers want delivery as soon as possible has been made. The objective with this chapter is to get an overview of the total time from the release of MOs to start of production. Other selections for this measurement can be seen in chapter 0 Waiting time to start when material is available. This selection contains 82,6% of MOs with a start date and the measurement has the resolution of one day. The average time is 12,99 days and as can be seen in Figure A-25 there is no specific trend and the variability is large.

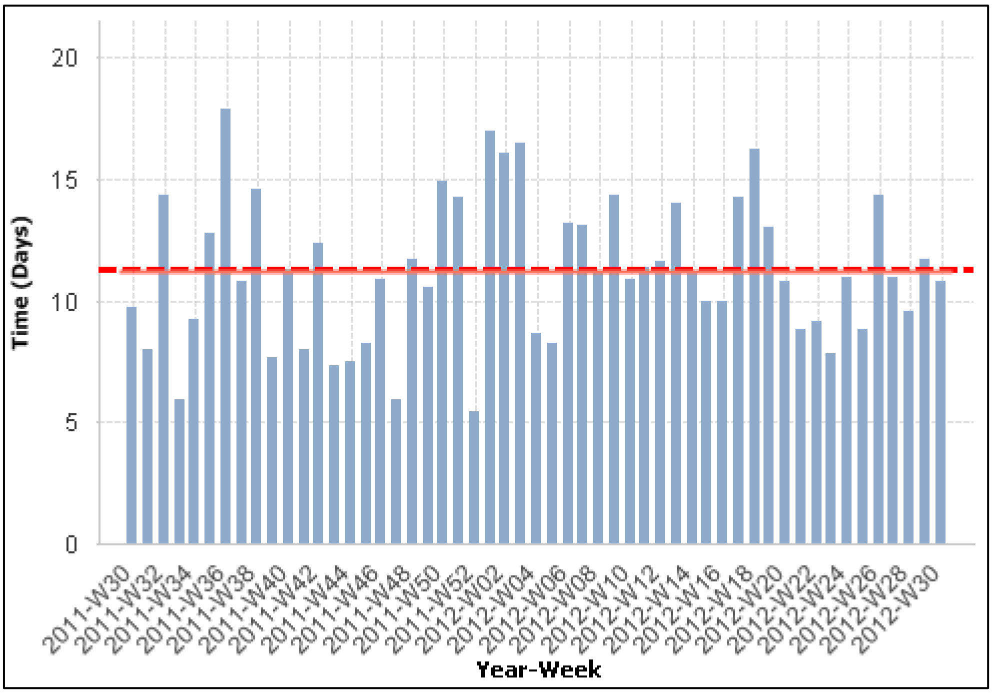

Figure A-25: Average amount of time in days per MO per week.

The distribution in Figure A-26 fits an exponential distribution badly with the tail as exception although the majority of values is still close to zero. The tail of the distribution is long.

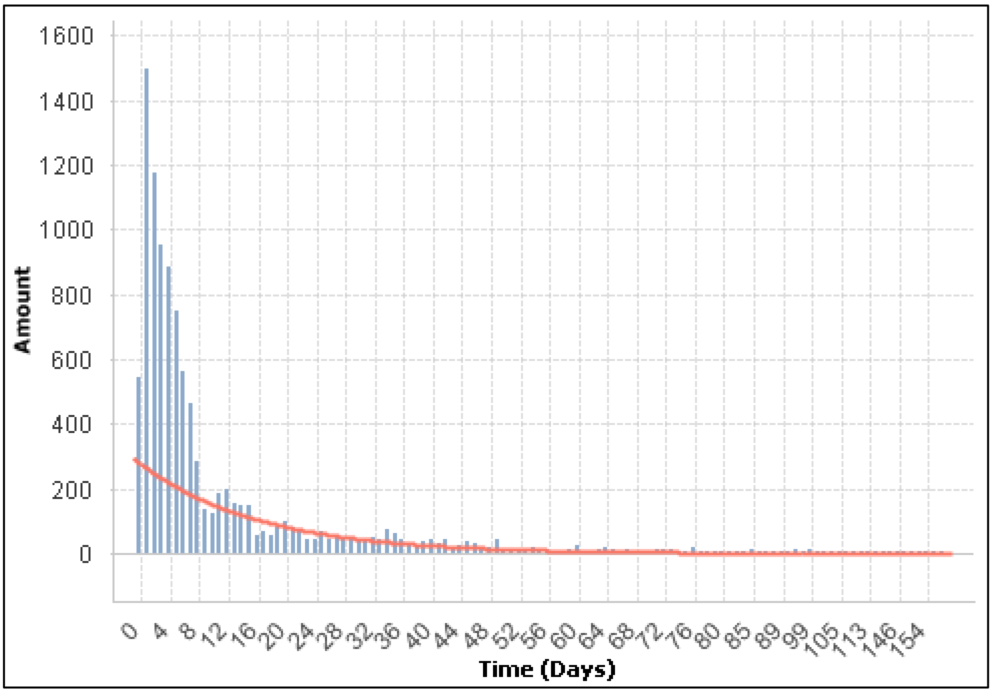

Figure A-26: Distribution of time in days rounded to integer.

The boxplot in Figure A-27 confirms that there are many large values. Large variability can also be seen in the boxplot.

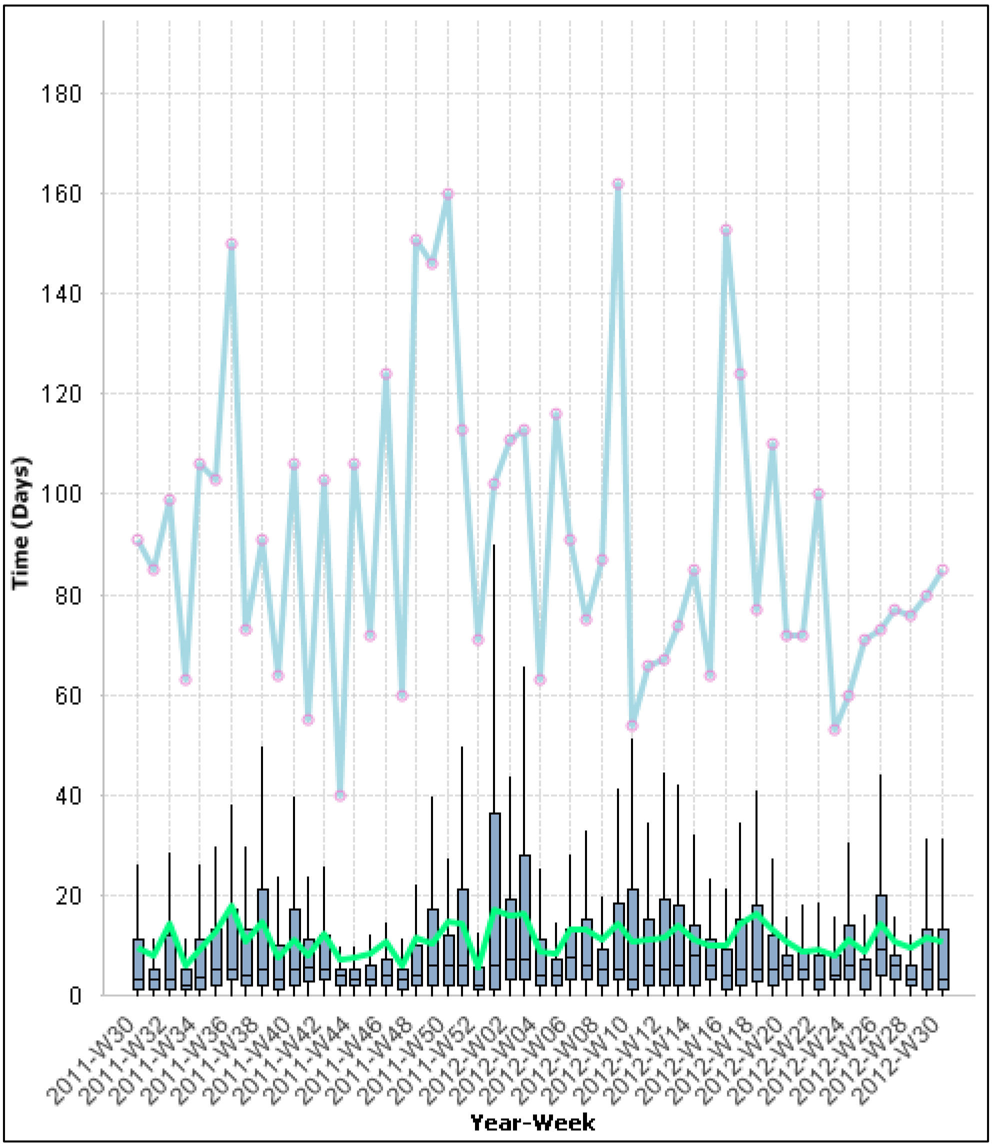

Figure A-27: Boxplot of time in days per week.

Production time

General case

In this measurement all MOs with a start and finish date has been included. This measurement has one day as resolution and because of this, if a MO is started and finished the same day, it is assumed to have taken 0,5 days in production time. If this assumption was not made many MOs would not take any time at all to produce. The average production time is 1,16 days which is low. As can be seen in

Figure A-28 the variability is low meaning that the process is steady, no clear trends can be spotted.

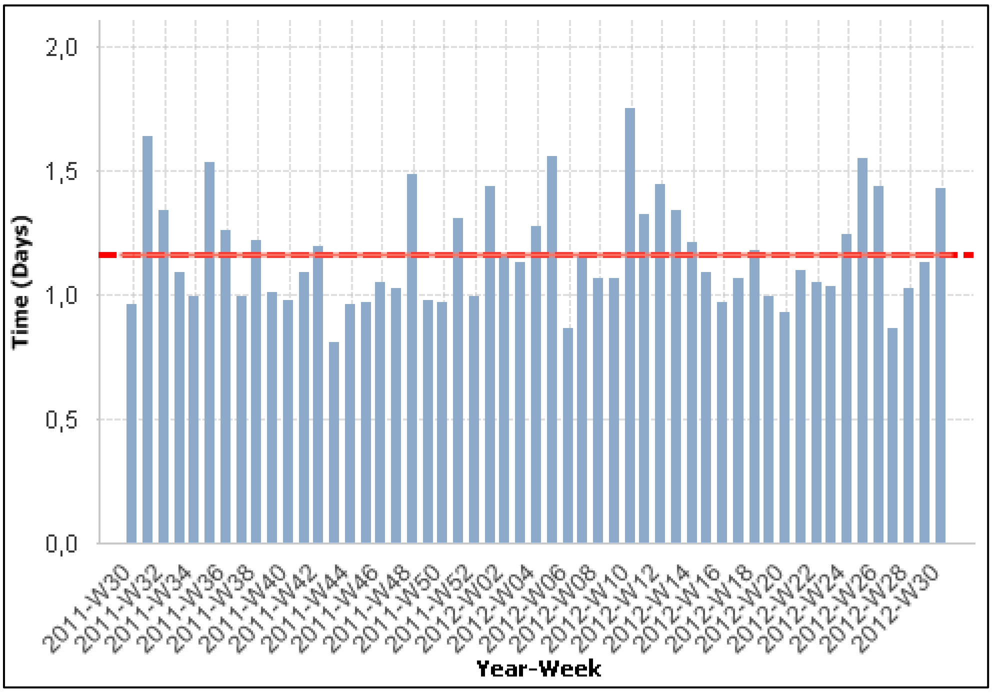

Figure A-28: Average amount of time in days per MO per week.

The distribution in Figure A-29 is exponentially distributed as expected and it is evident that many MOs are started and finished the same day.

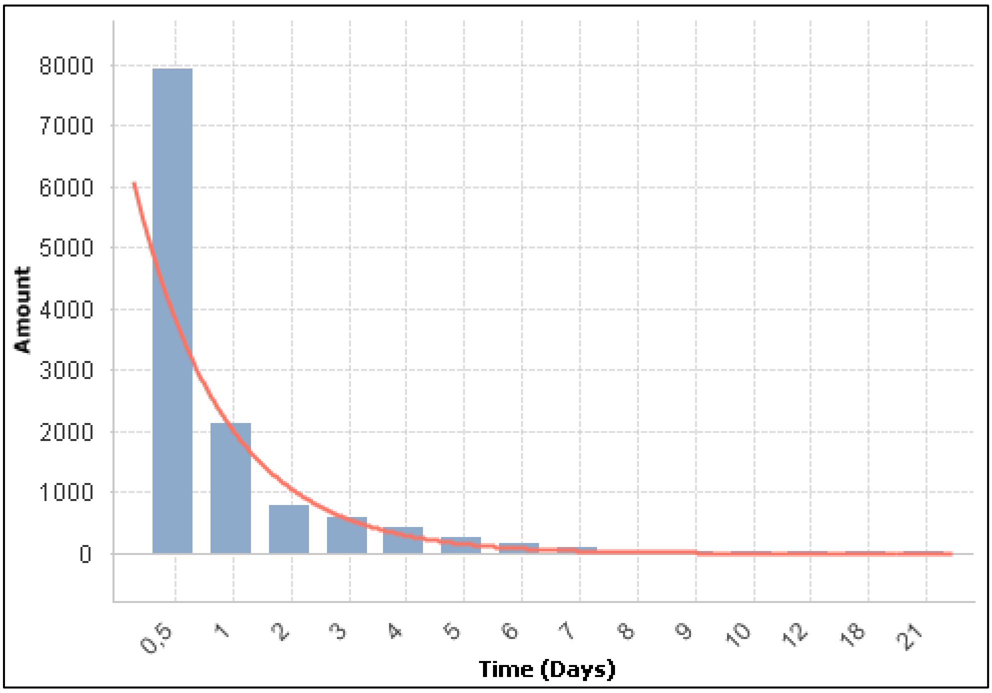

Figure A-29: Distribution of time in days.

The boxplot, Figure A-30, confirms that the process is stable over time. There are some extreme values driving the average some weeks but these occasions are more uncommon then the case when the maximum value is small.

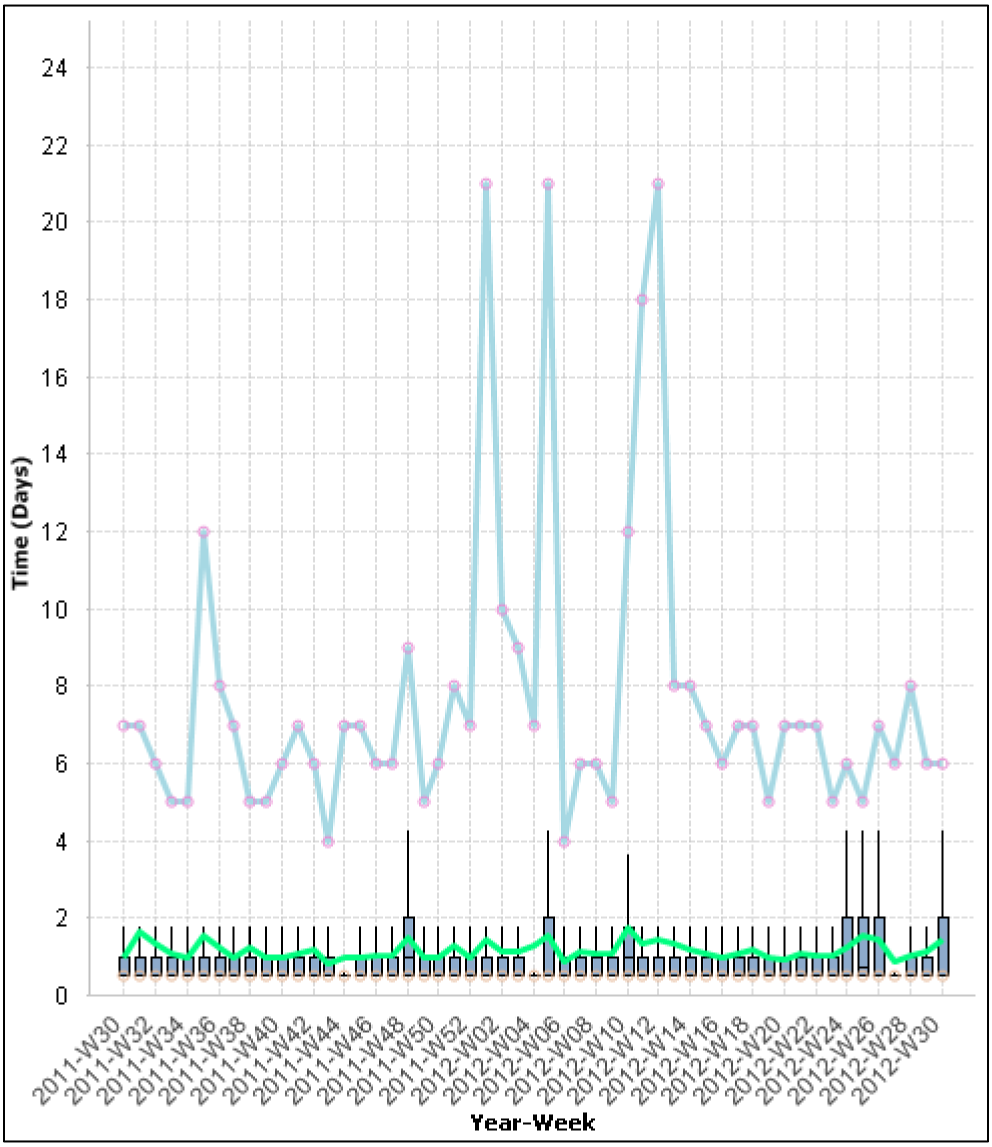

Figure A-30: Boxplot of time in days per week.

Other selections

Different selections have been made to test if the production time varies, e.g. CRD as soon as possible in combination with material availability. These will not be presented because nothing special has been discovered making these selections. The average production time has only a small variation between the selections and the only thing noteworthy is that the distribution of values in the boxplot increases when CRD is realistic (the box with whiskers takes up a larger span from minimum to maximum values).

Waiting time after production

General case

The general case in this measurement contains the whole population, which are all MOs that have an actual finish date reported in Movex. The average waiting time after production are 1,48 days, as can be seen in Figure A-31. The variability is high especially in 2012. A clear increasing trend can be spotted over the period. This measurement is on a daily basis, so if a route has a departure on the same day as the production is finished, the waiting time will be zero. This means that if the production is finished after the departure time, but on the same day, the waiting time will still be presented as zero in the results. The waiting time in this measurement must therefore be seen as a best case scenario.

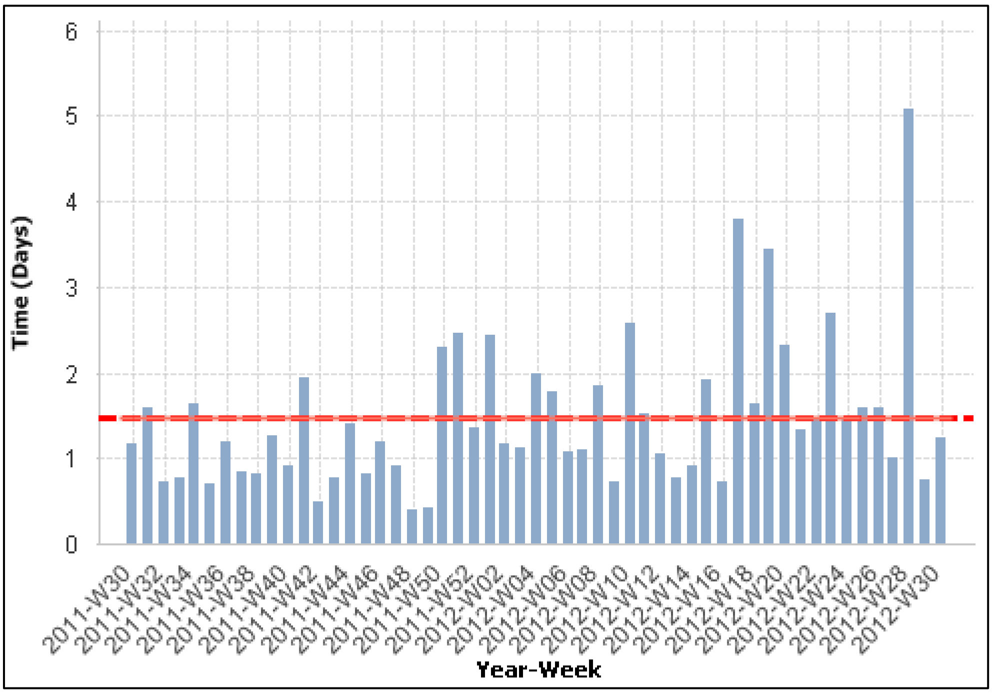

Figure A-31: Average amount of time in days per MO per week.

As can be seen in Figure A-32 the majority of values for the whole dataset, over 70%, are located at zero days. The exponential distribution trend line can therefore not be fitted with the actual distribution.

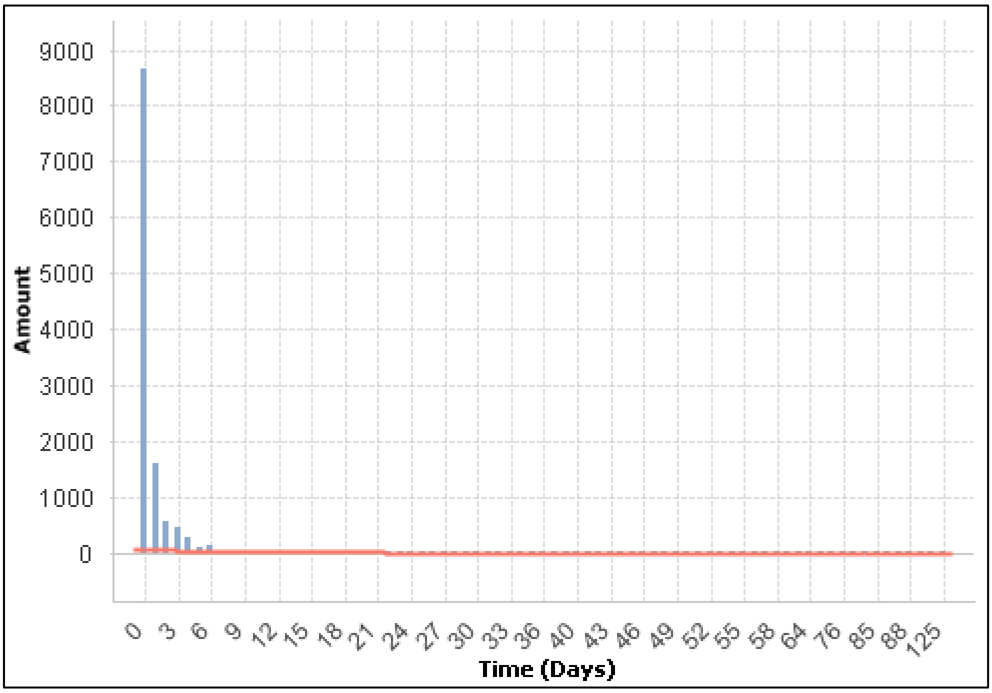

Figure A-32: Distribution of time in days rounded to integer.

When studying the distribution per week in the boxplot in Figure A-33, it can also be seen that the majority of all values are located close to zero. The average value per week does in almost all weeks lie above the top of the box. This means that a few extreme values drive up the average.

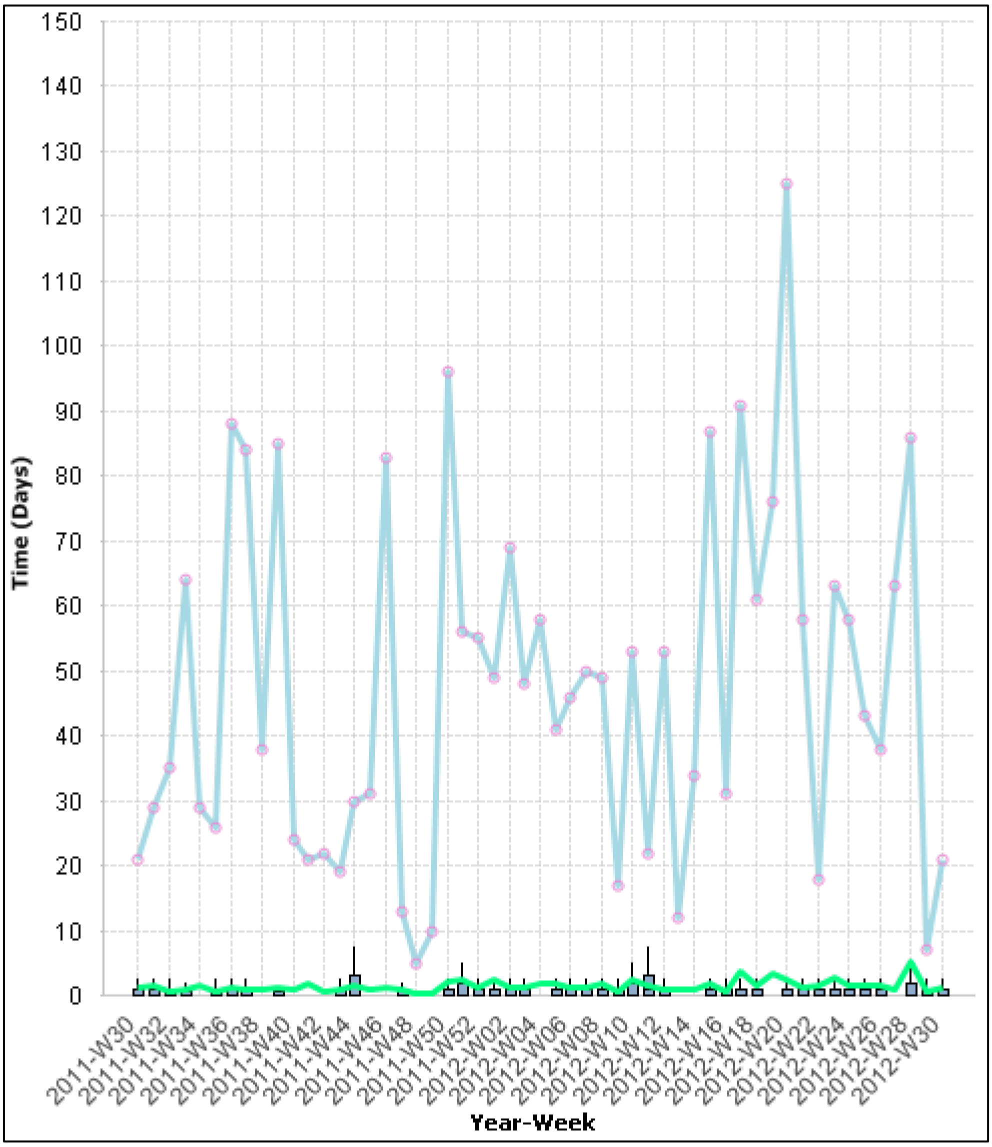

Figure A-33: Boxplot of time in days per week.

Selection CRD a.s.a.p.

When customers request delivery as soon as possible, which is the case in 83,5% of all MOs, the average waiting time after production decreases to 0,47 days, see Figure A-34. There is still some variability, but not as much as in the general case. Having an average waiting time for transportation of only half a day is not very long, so this must be seen as satisfactory.

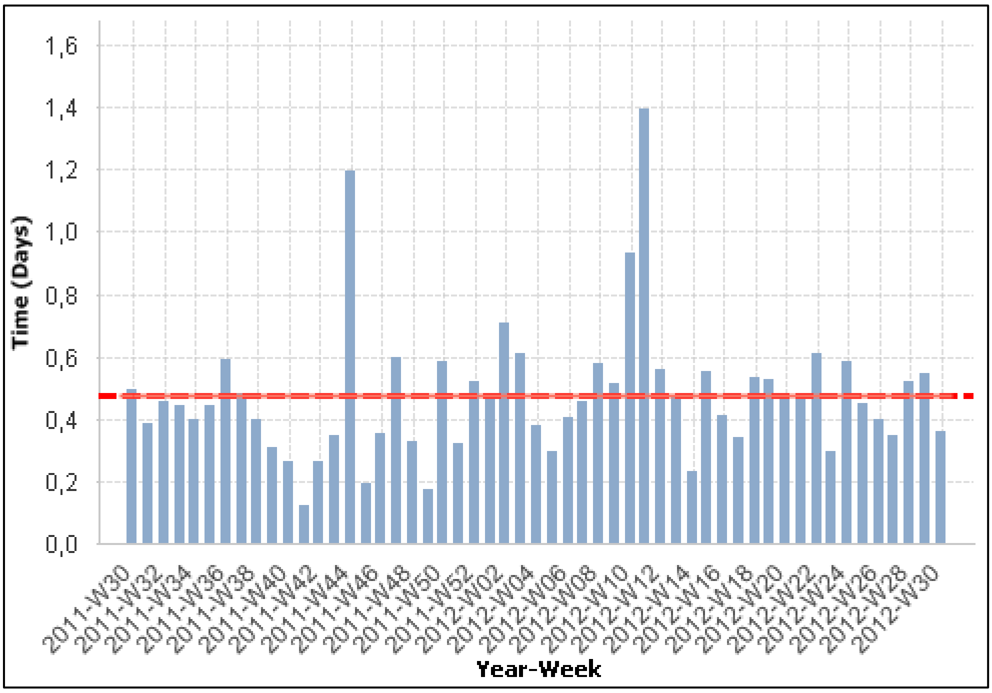

Figure A-34: Average amount of time in days per MO per week.

The distribution of waiting time after production for all MOs that customers request as soon as possible can be seen in Figure A-35. The majority of all values are located at zero, 75,7% of the total amount. The exponential distribution trend line fits the actual distribution somewhat well.

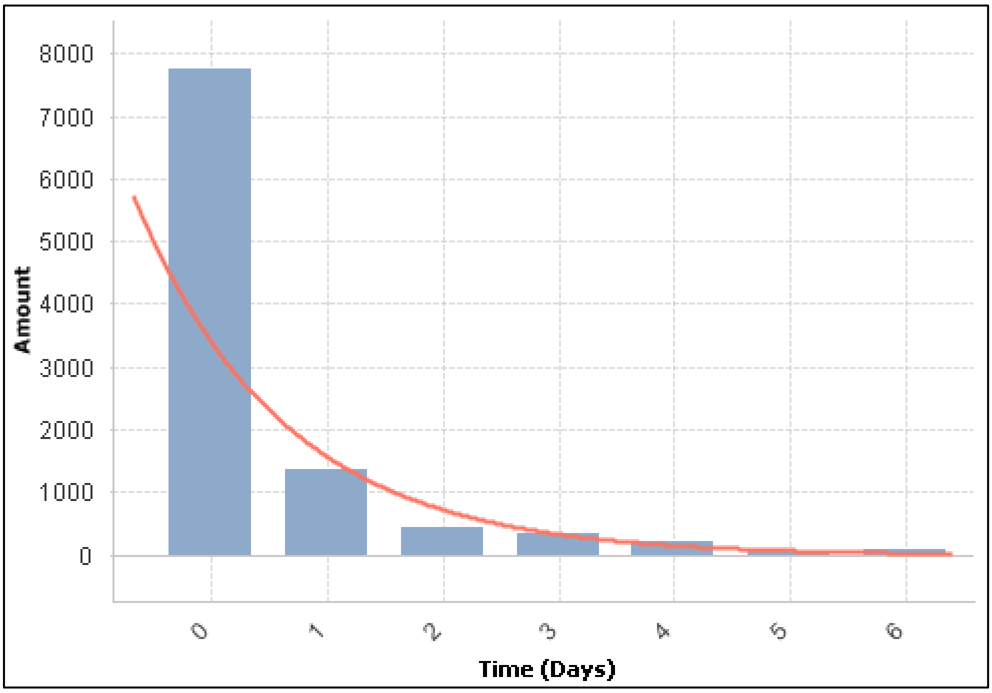

Figure A-35: Distribution of time in days rounded to integer.

In the boxplot, Figure A-36, the maximum values are much lower than in the general case. The reason for this is that the longest a MO that should be delivered as soon as possible can wait for transportation is 6 days. This is because for every route to customers there is at least one departure per week. The process is very stable which is satisfying.

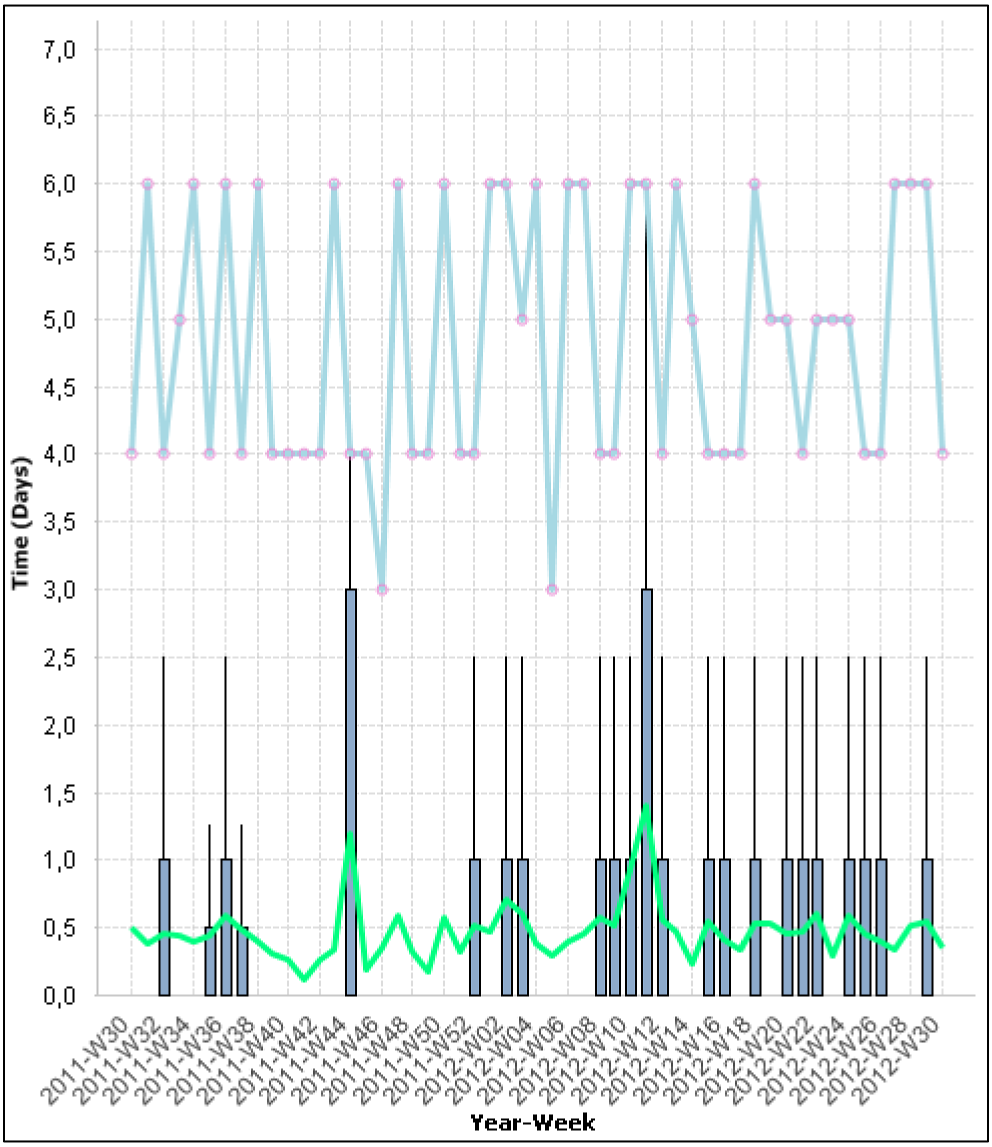

Figure A-36: Boxplot of time in days per week.

Selection realistic CRD

When customers request delivery on a specific realistic date, which is the case for 16,5% of all MOs, the average waiting time after production increases to 6,56 days. As can be seen in Figure A-37 the variability is high, with the weekly average going from more than 25 days to almost zero. These 16,5% of MOs increases the waiting time after production for all MOs by three times the time. Having these MOs waiting when finished, with much value added to them, for almost a week on average before being transported is not very lean. This tie up a lot of capital as well as the longer a finished product is being stored, the risk of it being damaged increases. When a MO with a realistic customer request date is finished too early customer service sometimes contacts the customer to see if they would like to receive the CO earlier. This results in a lot of contact with customers which take up time and resources, where in many cases an earlier delivery is not wanted according to the data. This drives the cost of finishing MOs too early even more in addition to the tied up capital.

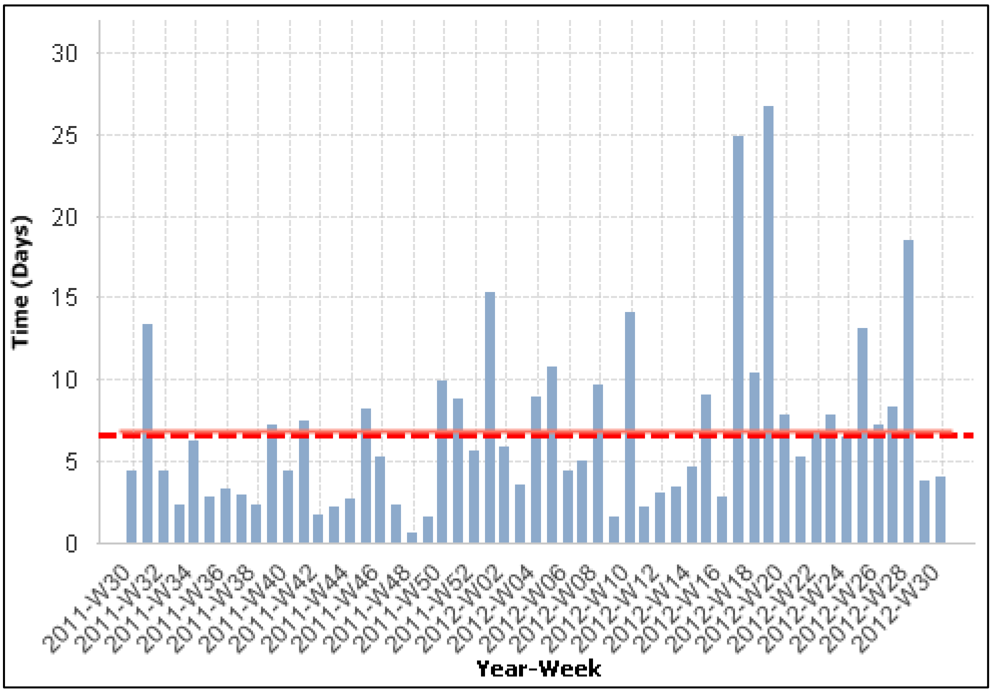

Figure A-37: Average amount of time in days per MO per week.

In Figure A-38 the distribution of this selection can be seen. Many MOs in this selection are finished on the day of transportation, but there are also many that are finished much earlier. It does however need to be noted that some of the MOs that have a waiting time of zero or only a few days could be MOs that initially were finished much too early. Customers could, after being contacted by customer service, have accepted delivery on an earlier date. The customer request date would then be brought forward.

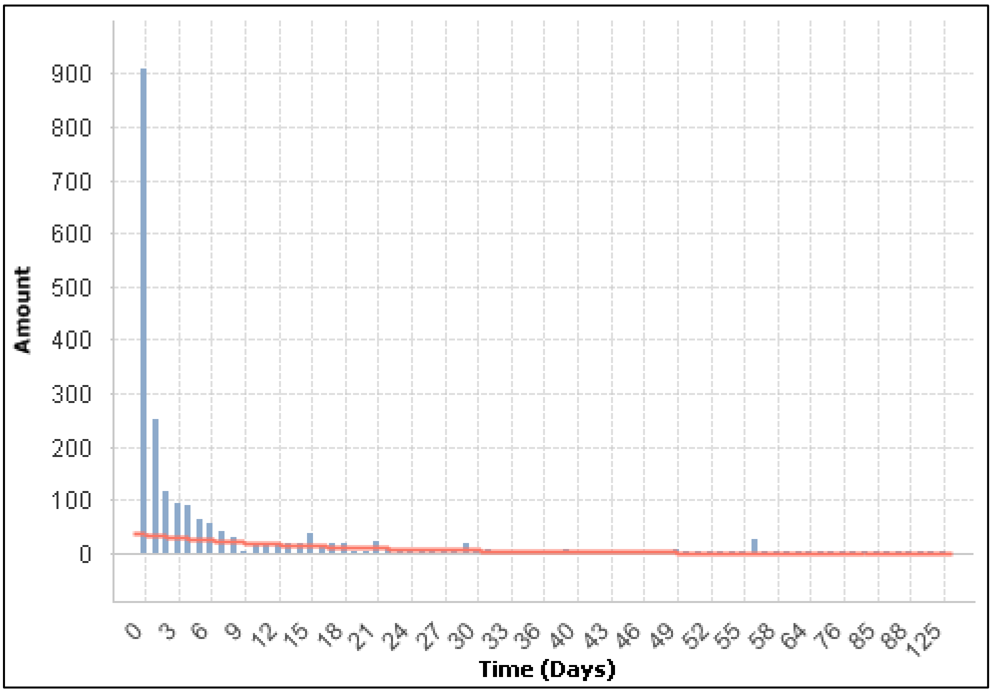

Figure A-38: Distribution of time in days rounded to integer.

When studying the boxplot in Figure A-39 it can be seen that there is a large variability of values. The average value is almost always quite a bit larger than the median, which means that there are many extreme values that drive up the average. This process is very unstable and some action must be taken to reduce this waiting time.

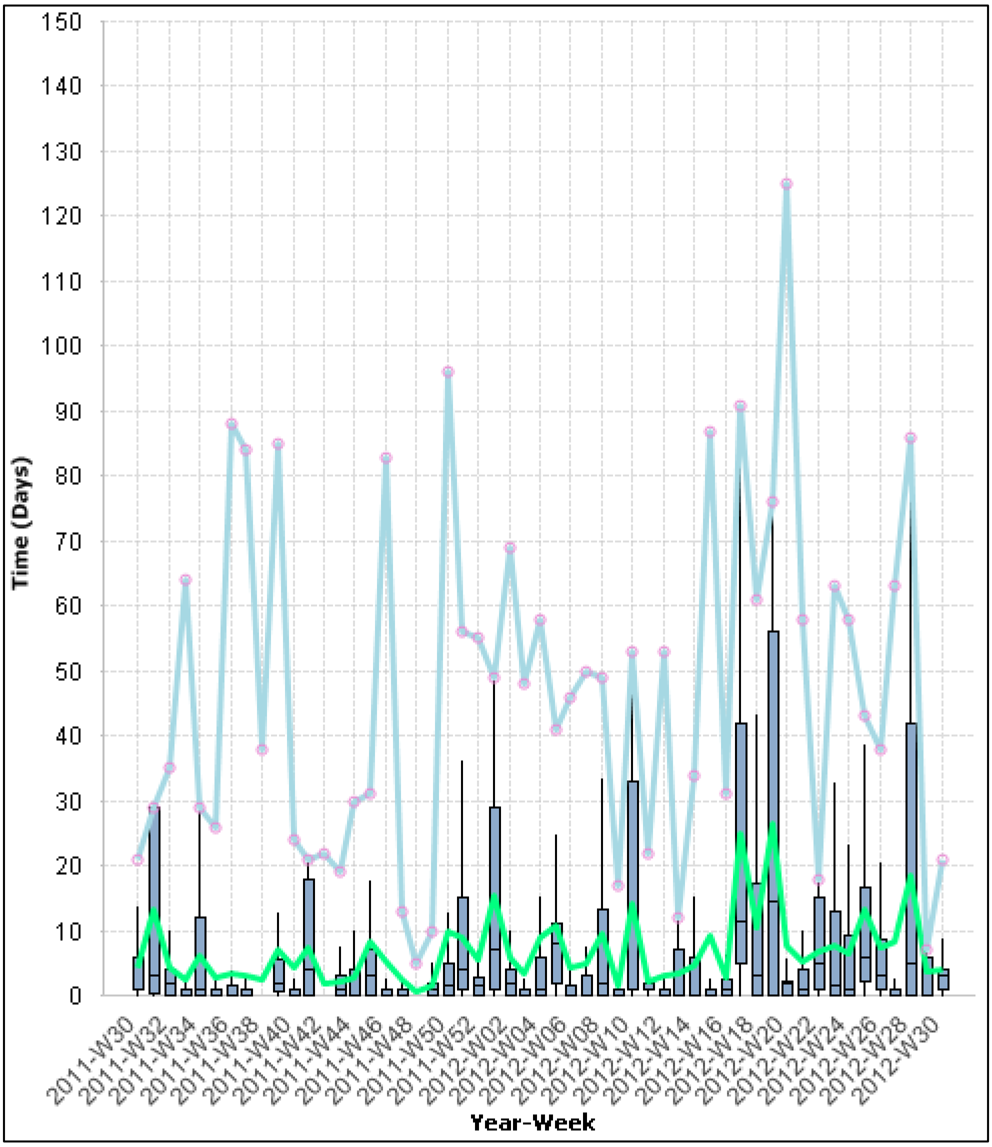

Figure A-39: Boxplot of time in days per week.

Other selections

When studying how material availability affects the waiting time, it could be seen that the average values was affected somewhat. When material was available from CO entry date the average waiting time after production was 0,85 days and when material was not available from CO entry date the average was 1,65 days. Apart from the amplitude of the graphs, not much else was different from the general case. When comparing this to the results from different CRD statuses, it has been concluded that CRD status has a much larger impact on the waiting time after finished production than material availability has. The graphs illustrating material availability selections will therefore not be presented in this report.

Internal lead time

General case

When measuring the internal lead time all MOs with a realistic CRD have been removed. This is because if CRD is realistic waiting time would be included in the measurement. When this selection has been made 82,6% of all MOs are selected. The internal lead time has some variability as can be seen in Figure A-40. The average internal lead time is 13,39 days. This measurements resolution is one day.

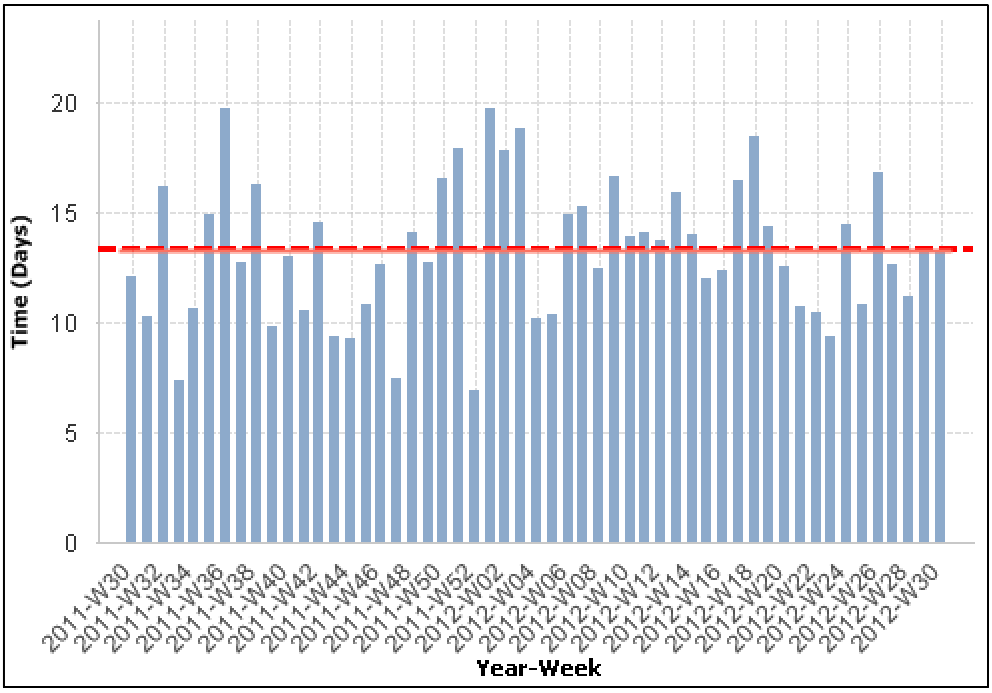

Figure A-40: Average amount of time in days per MO per week.

The distribution in Figure A-41 has some resemblance with a normal distribution albeit small.

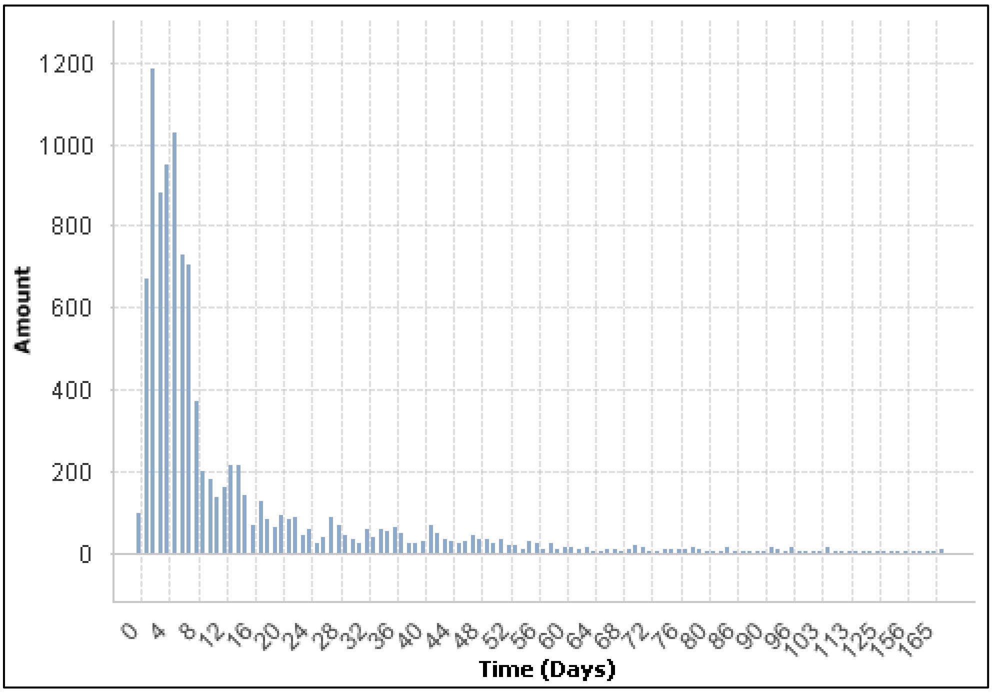

Figure A-41: Distribution of time in days rounded to integer.

The boxplot in Figure A-42 shows that there is a large variability in all cases except for the median and low values. The maximum values are fluctuating and the box sizes vary from being dense to spread out. This process is unstable which will be unsatisfying for the customers as the total lead time will be affected.

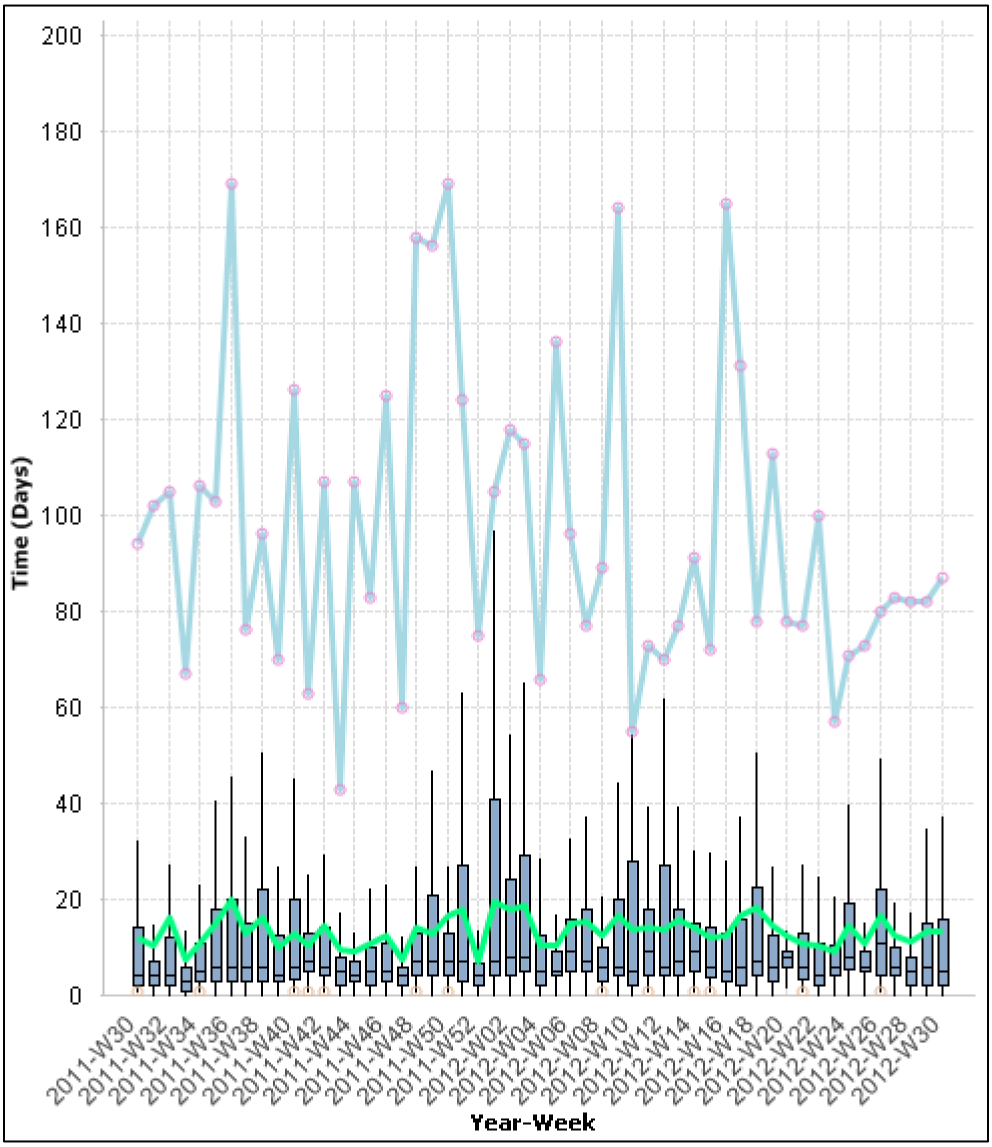

Figure A-42: Boxplot of time in days per week.

Selection material available (and CRD a.s.a.p.)

When material is available from CO entry date (and customers request delivery as soon as possible) the amount of MOs selected are 35,5% and the average internal lead time decreases drastically to 4,38 days. The variability in Figure A-43 is low but there seems to be an short increasing trend in the beginning of the period. Of the 4,38 days internal lead time, 3,32 days are in average spent waiting for production to start which is unnecessary. In other words 75,8% of the internal lead time is spent waiting in this step.

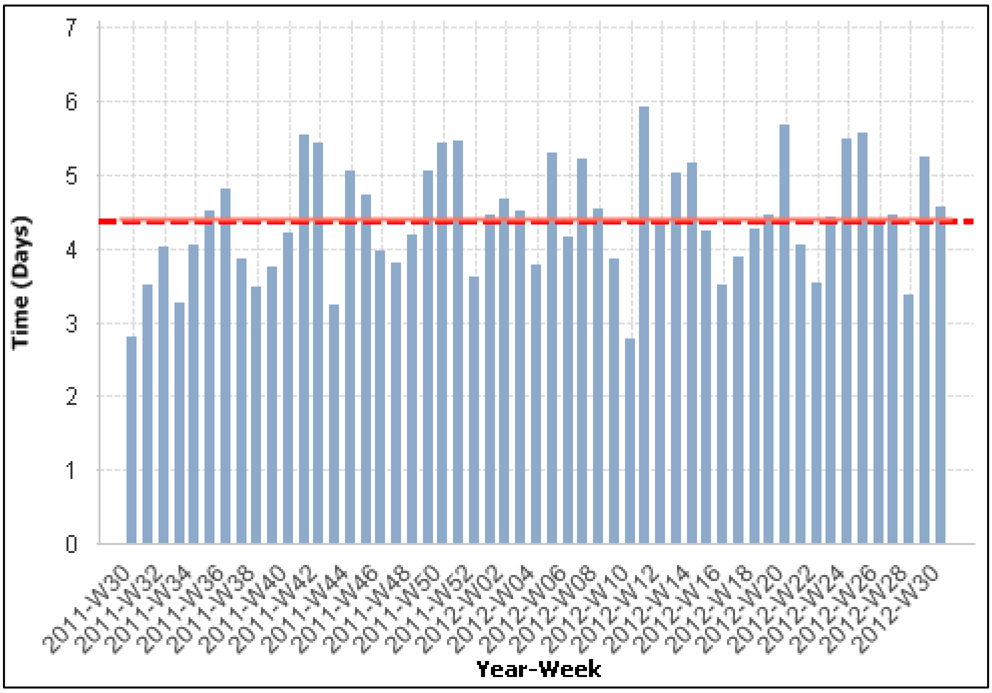

Figure A-43: Average amount of time in days per MO per week.

The distribution in Figure A-44 is still somewhat normally distributed with a much shorter tail this time.

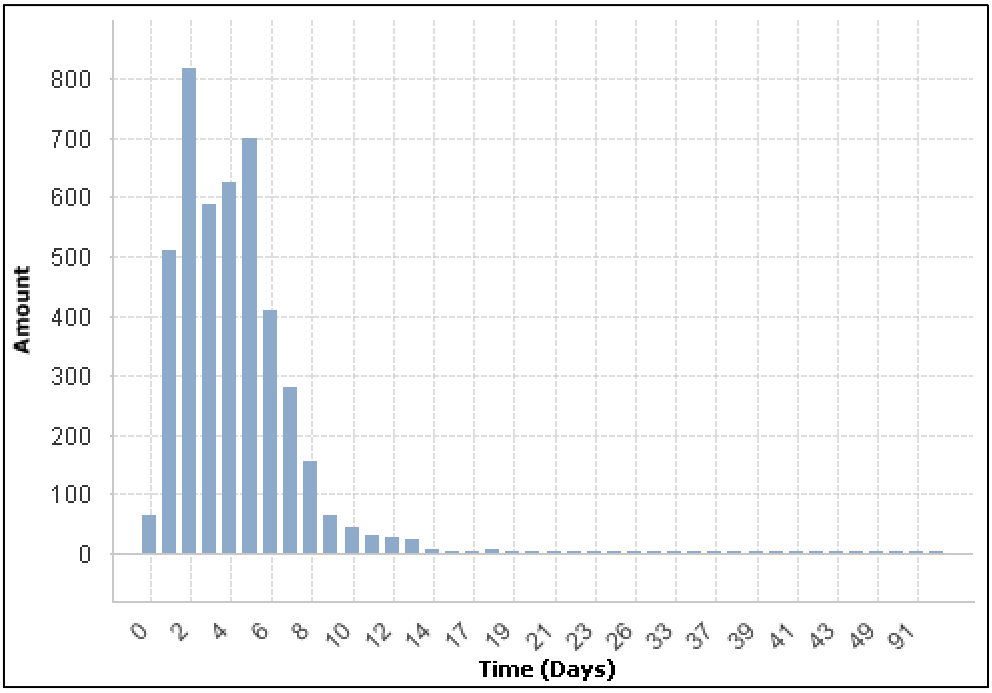

Figure A-44: Distribution of time in days rounded to integer.

In the boxplot, Figure A-45, no specific trend can be spotted. The maximum values have high variation affecting the average slightly but the boxes and average is still steady with low variation.

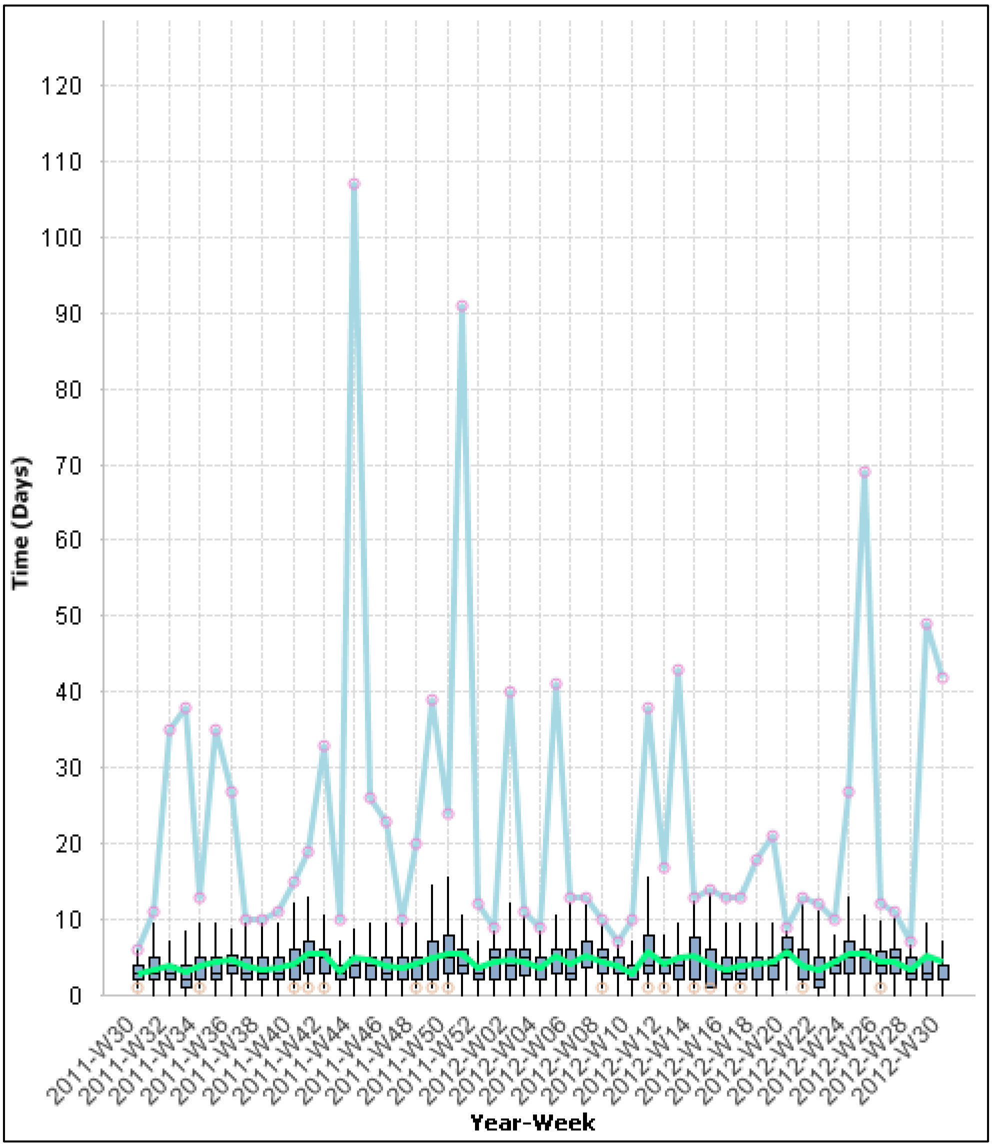

Figure A-45: Boxplot of time in days per week.

Selection material not available (and CRD a.s.a.p.)

In this case the selection contains 37,7% of all MOs and the average increases to 17,00 days. The amount of time that is spent waiting for production to start increases to 5,01 days after material has become available. The increase is due to the fact that the system specifies two days for receiving and put away when in reality this often is made the same day as the material is received. This in turn hinders the planners from rescheduling the MO in advance, instead rescheduling has to be performed when material is registered as available on a location. This does not change the fact that the MO still waits a long time for production to begin. In Figure A-46 the variability increases from the previous selection although it seems to be decreasing towards the end of the period.

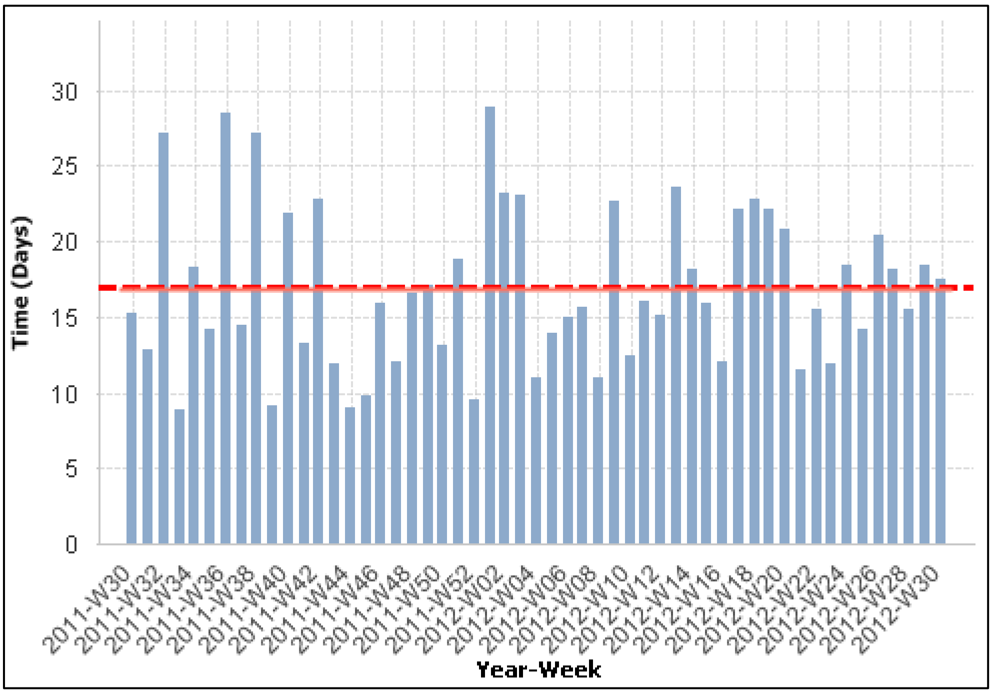

Figure A-46: Average amount of time in days per MO per week.

The distribution in Figure A-47 looks similar to the general case.

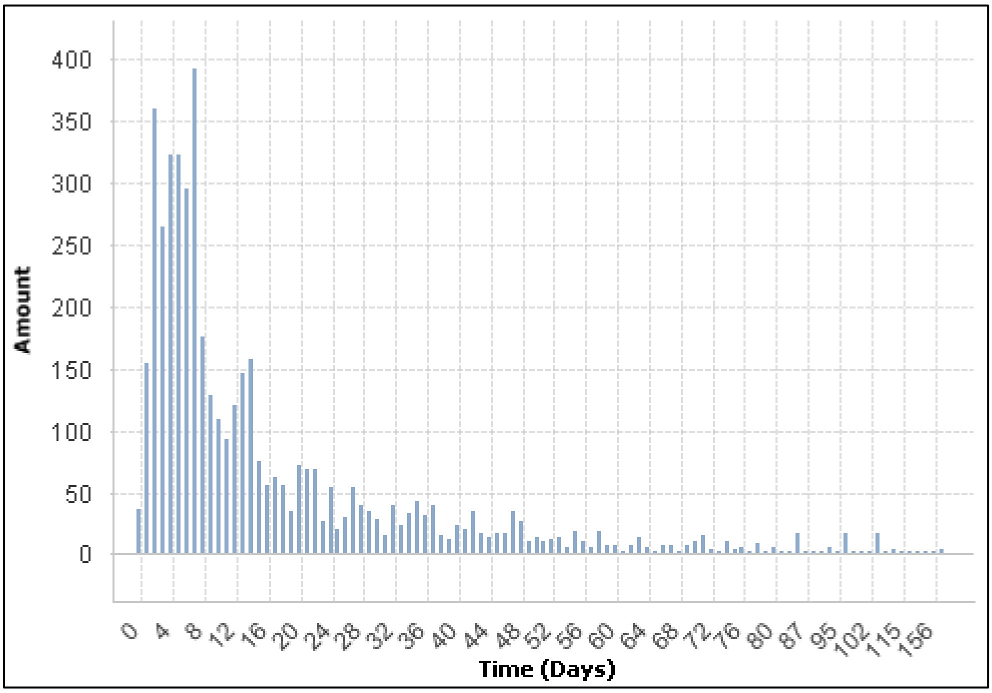

Figure A-47: Distribution of time in days rounded to integer.

The boxplot in Figure A-48 also has some similarities with the general case. One important difference though is that the boxes and whiskers are more spread out which indicates that the process is more unstable.

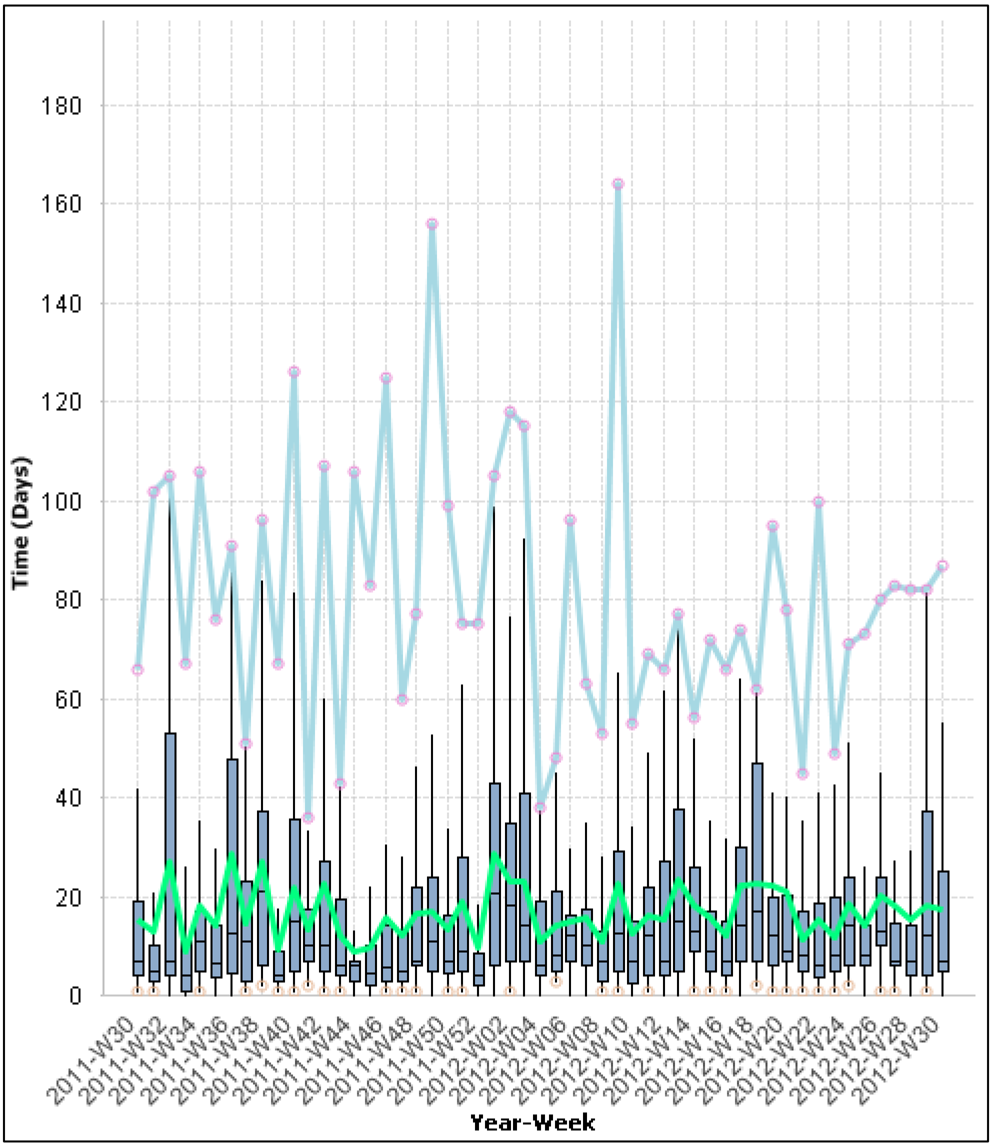

Figure A-48: Boxplot of time in days per week.

Total lead time

General case

Besides internal lead time the total lead time also takes waiting time after production as well as transportation time into account. The waiting time after production is as mentioned in chapter 0 Waiting time after production a best case calculated time and the transportation time used is the time transportation takes according to Movex. As with the internal lead time, it is only meaningful to study the MOs where customers request delivery as soon as possible, which is the case for 83,5% of the MOs. The average total lead time for this selection of MOs is 17,88 days, as can be seen in Figure A-49.

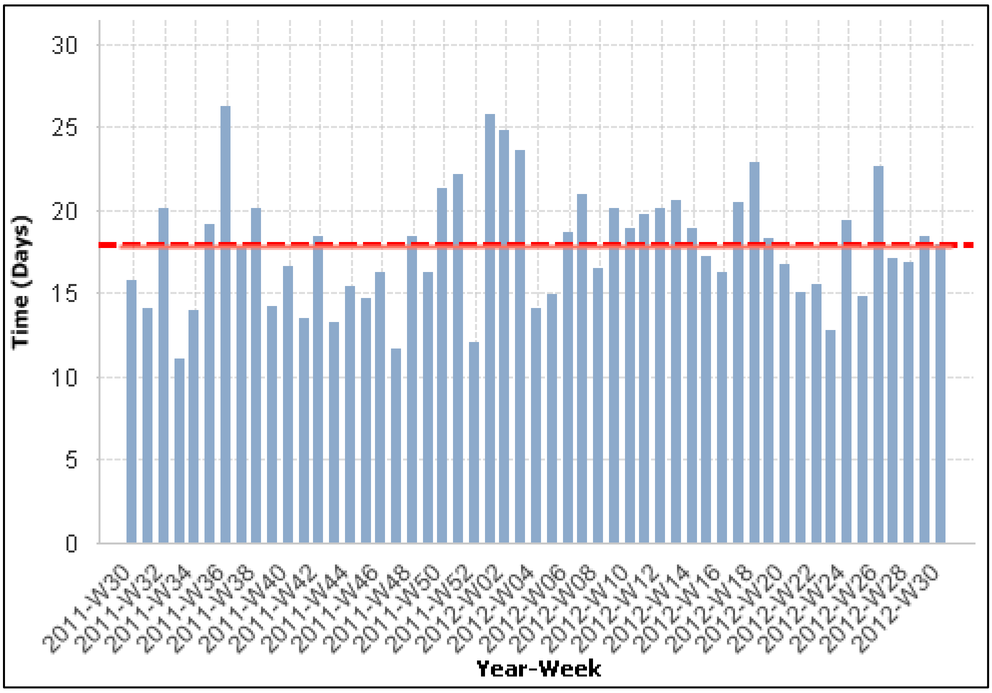

Figure A-49: Average amount of time in days per MO per week.

The majority of values are distributed between 1 and 22 days, with a resemblance to a normal distribution, see Figure A-50.

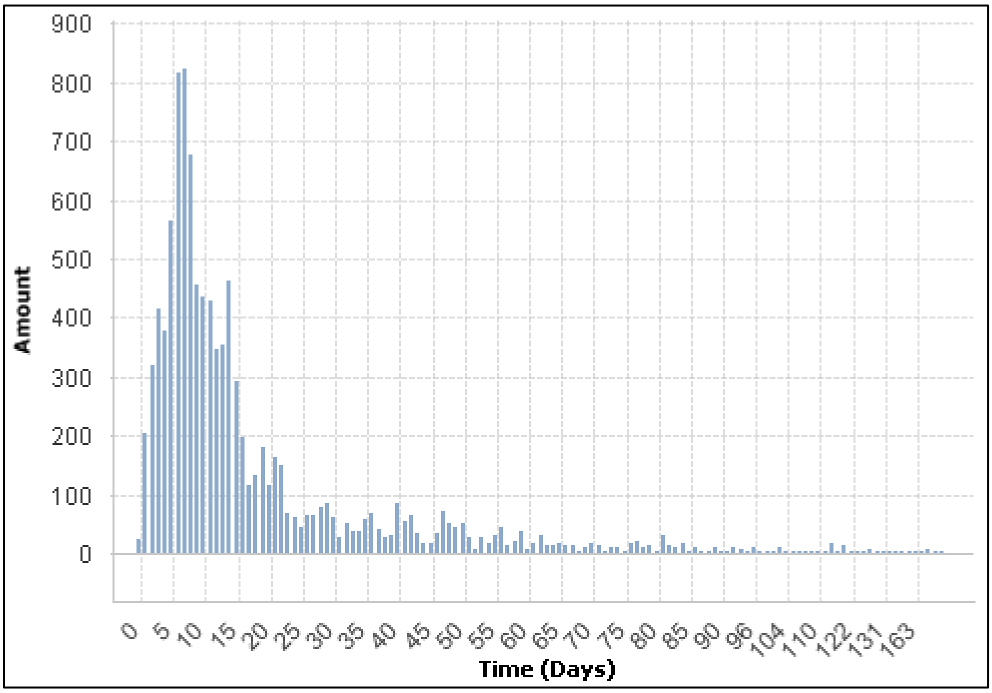

Figure A-50: Distribution of time in days rounded to integer.

The boxplot in Figure A-51 shows that there is some variability in the total lead time per week. The average values are often much larger than median values, which indicated that there are a few extreme values that drive up the average. The boxes with whiskers are somewhat spread out between the maximum and minimum values.

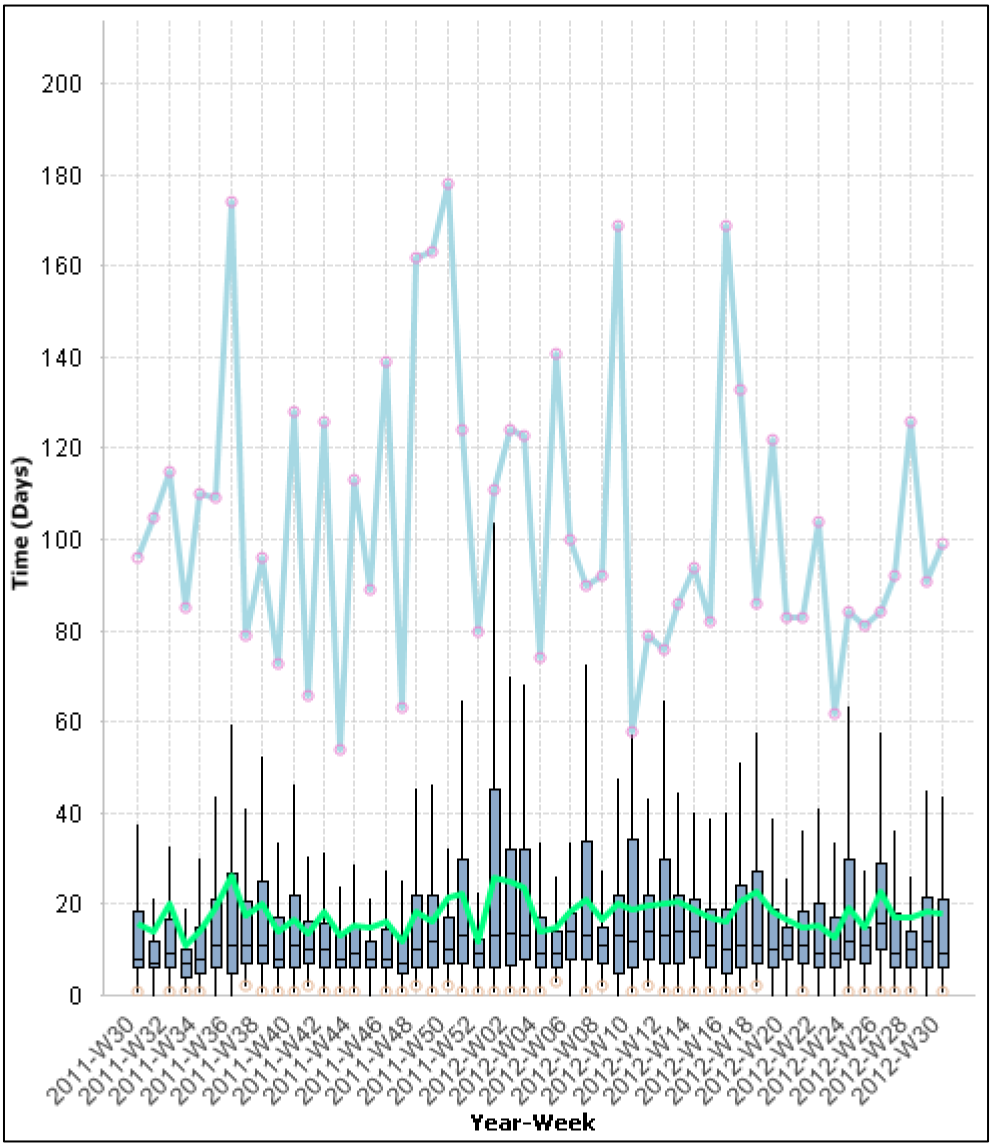

Figure A-51: Boxplot of time in days per week.

Other selections

When material was available from CO entry date the average total lead time was 8,19 days. When material was not available from CO entry date the average total lead time increased to 21,73 days. Apart from amplitude of the graphs there was not much that was different from the same cases in chapter 0 Internal lead time. There is not much more to say about these cases than what already has been said, so for that reason these graphs will not be included in the report.

Days too late from CRD

General case

It is only meaningful to analyze this measurement when customers have a realistic CRD. This is because that when customers request delivery as soon as possible this measurement will be the same as total lead time. This selection represents 16,5% of all MOs. MOs that have a realistic CRD are on average 2,99 days late, Figure A-52 also shows that the average per week fluctuates a lot. The measurement's resolution is one day and as with the total lead time, waiting time after production is a calculated value and the transportation time used is the time transportation takes according to Movex.

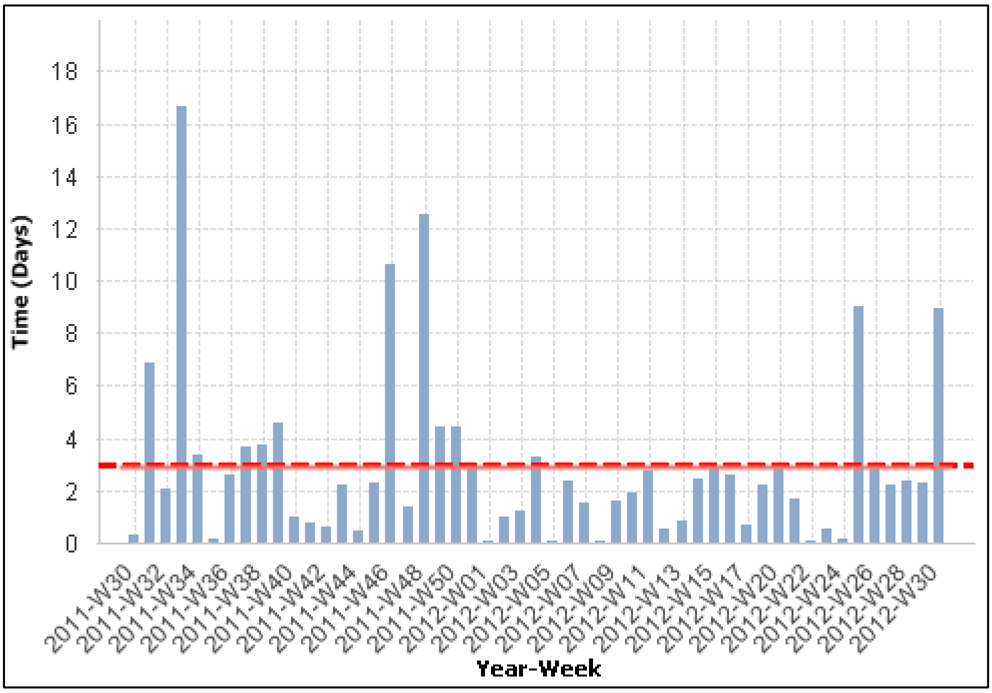

Figure A-52: Average amount of time in days per MO per week.

The distribution that can be seen in Figure A-53 shows that a large majority of values are at zero days, 73,6%. This means that the CRD is fulfilled in most cases, while the rest of the MOs, 26.4%, increase the average amount of days too late from CRD with almost 3 days. The trend line is a exponential function fitted to the data.

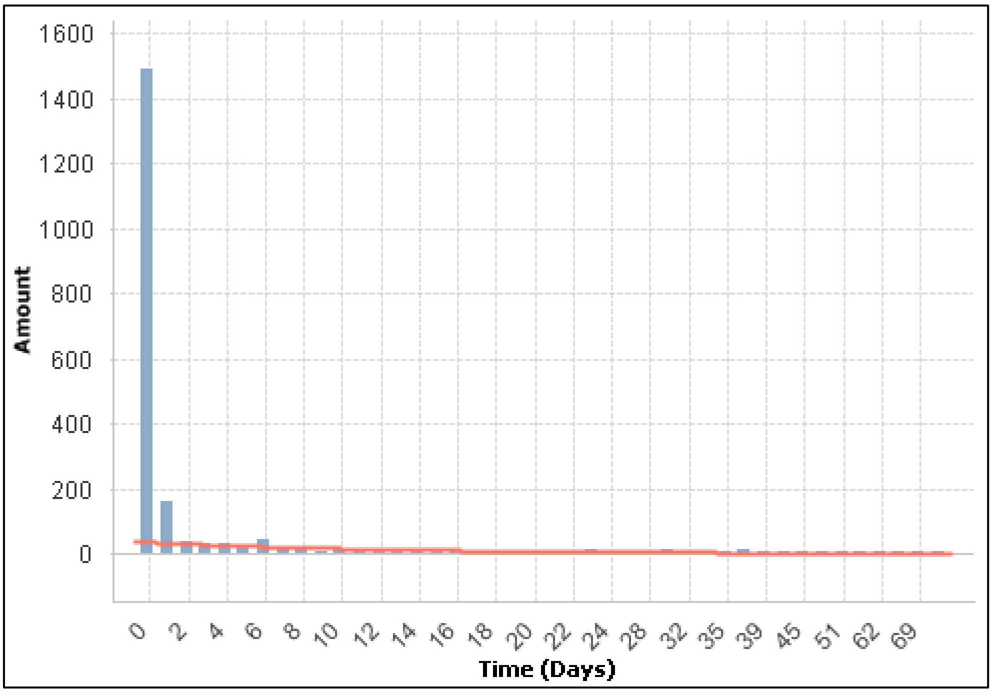

Figure A-53: Distribution of time in days rounded to integer.

The boxplot in Figure A-54 shows that there is a large variability in values, especially the maximum values. During most weeks the median is located at zero while the average is higher, this also confirms that the extreme values drive up the average.

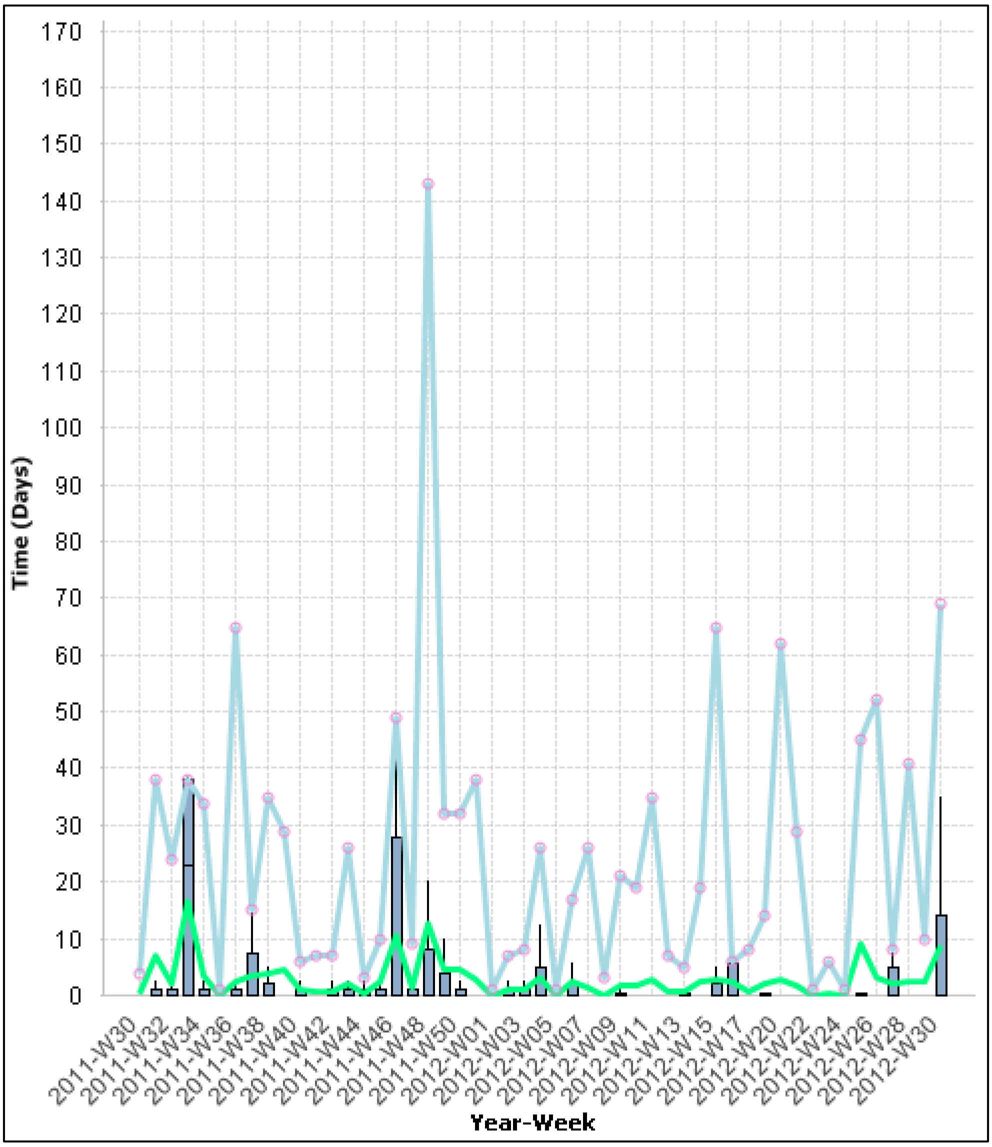

Figure A-54: Boxplot of time in days per week.

Selection material available (and realistic CRD)

When material is available from CO entry date (and CRD is realistic) the average amount of days too late decreases to 0,57 days as can be seen in Figure A-55. This selection is represented by 4,4% of all MOs. The variability is high, although lower than in the general case, and a slightly increasing trend can be spotted.

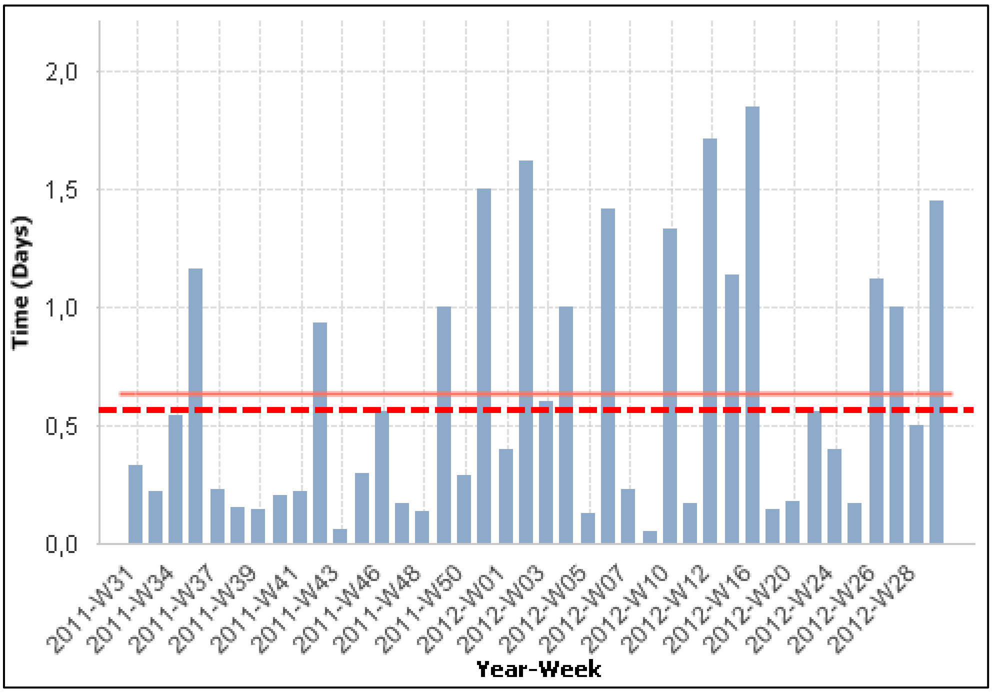

Figure A-55: Average amount of time in days per MO per week.

The distribution in Figure A-56 has a similar appearance to the general case, with a large majority at zero days.

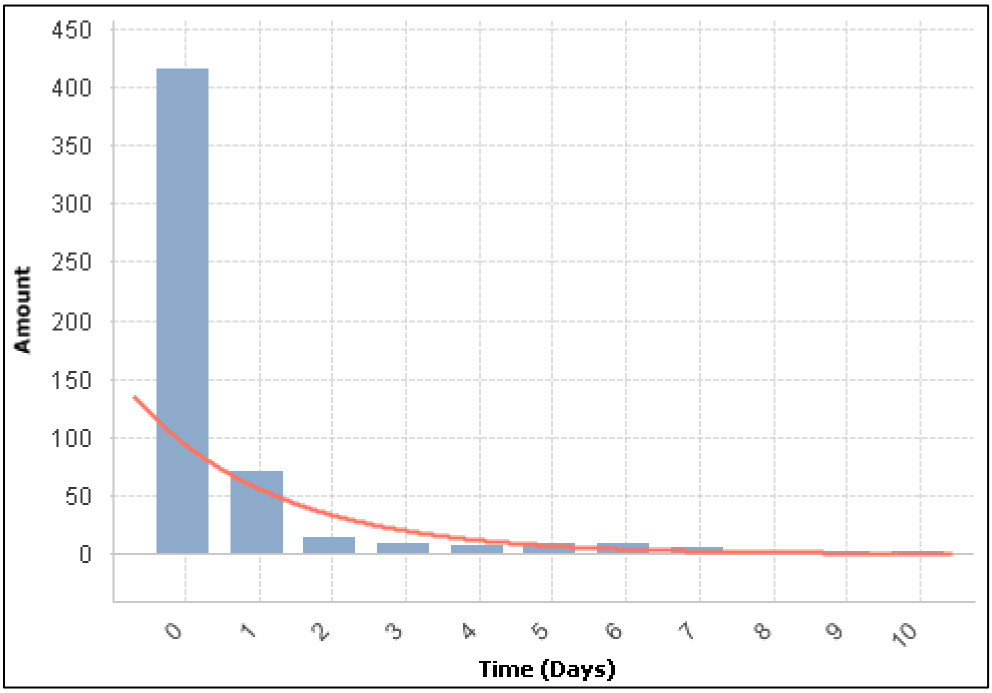

Figure A-56: Distribution of time in days rounded to integer.

The boxplot in Figure A-57 shows that the variability per week is much lower than in the general case, although it is still quite high.

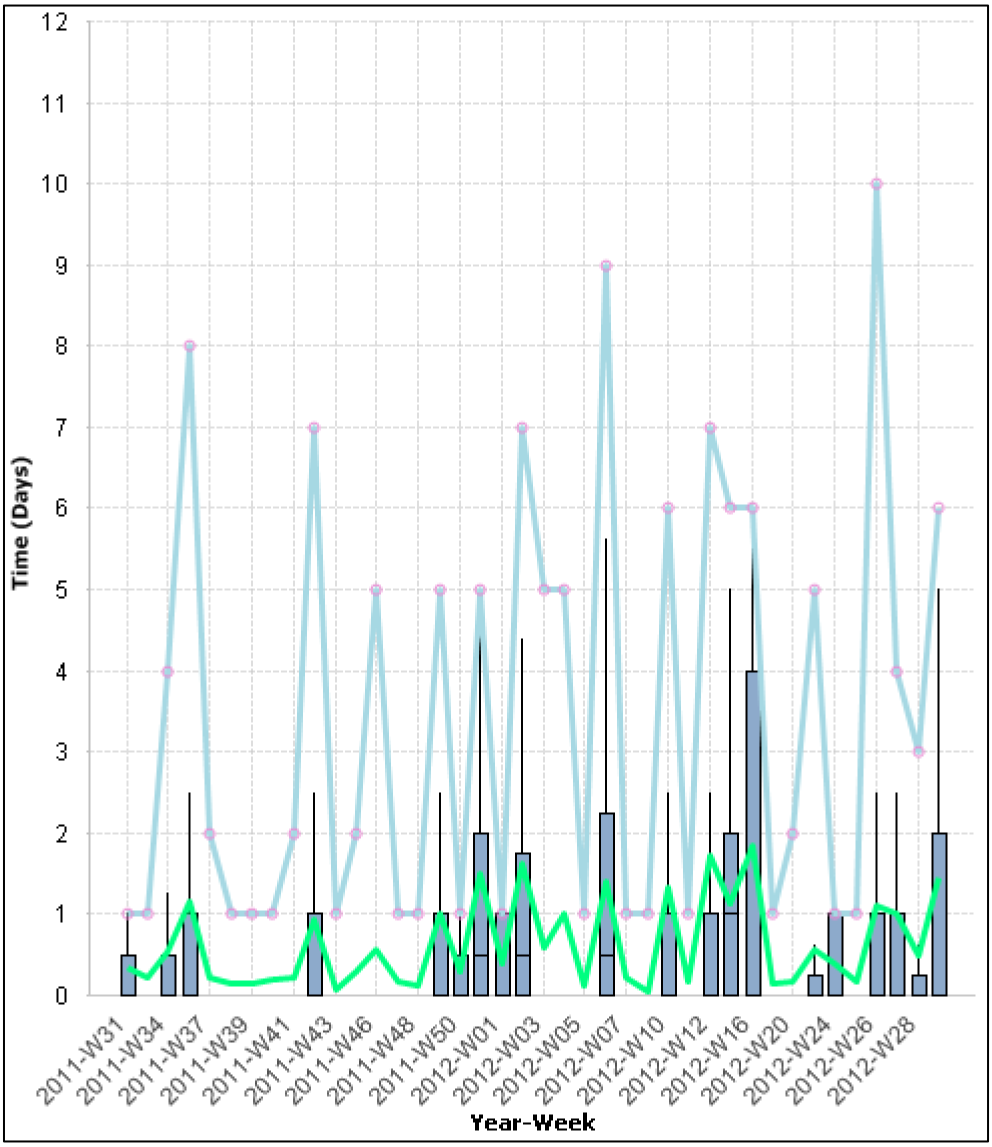

Figure A-57: Boxplot of time in days per week.

Selection material not available (and realistic CRD)

When material is not available from CO entry date (and CRD is realistic) the average amount of days too late increases to 3,52 days as can be seen in Figure A-58. This selection is represented by 9,3% of all MOs. The variability is high as in the general case.

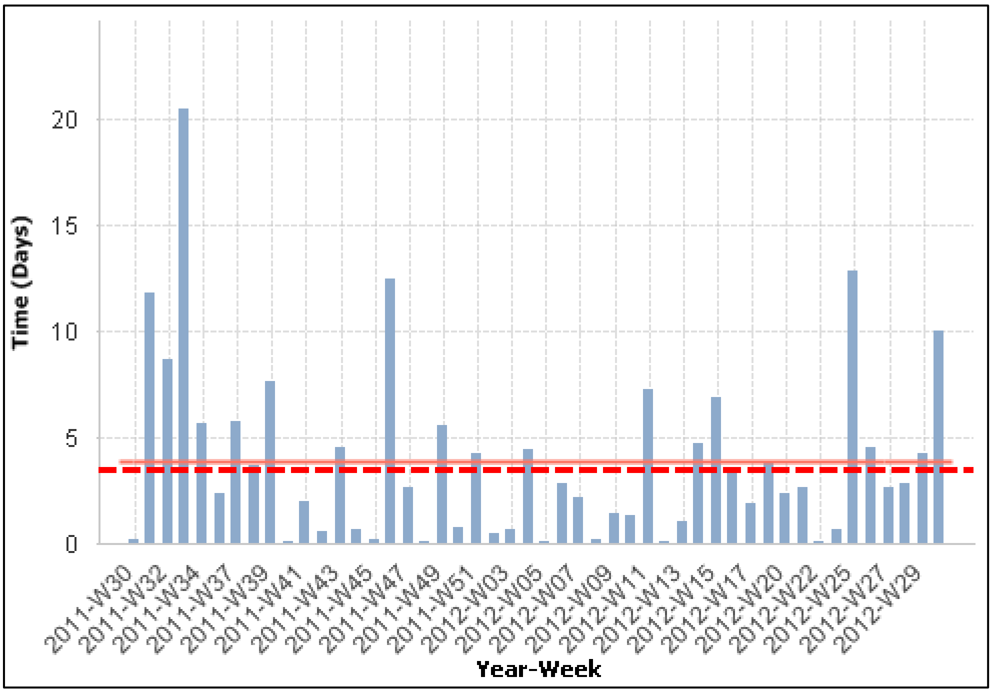

Figure A-58: Average amount of time in days per MO per week.

The distribution for this selection can be seen in Figure A-59, as in the general case, the majority of values are at zero days.

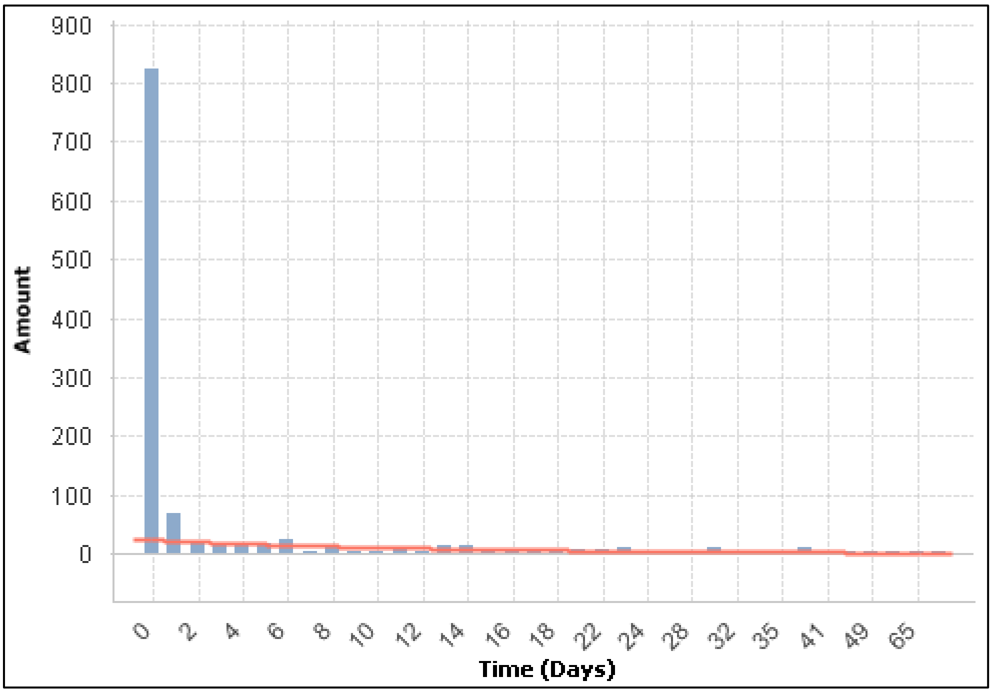

Figure A-59: Distribution of time in days rounded to integer.

The boxplot in Figure A-60 shows that there is a large variability in all values except the median, which in most cases is located at zero. The process is very unstable.

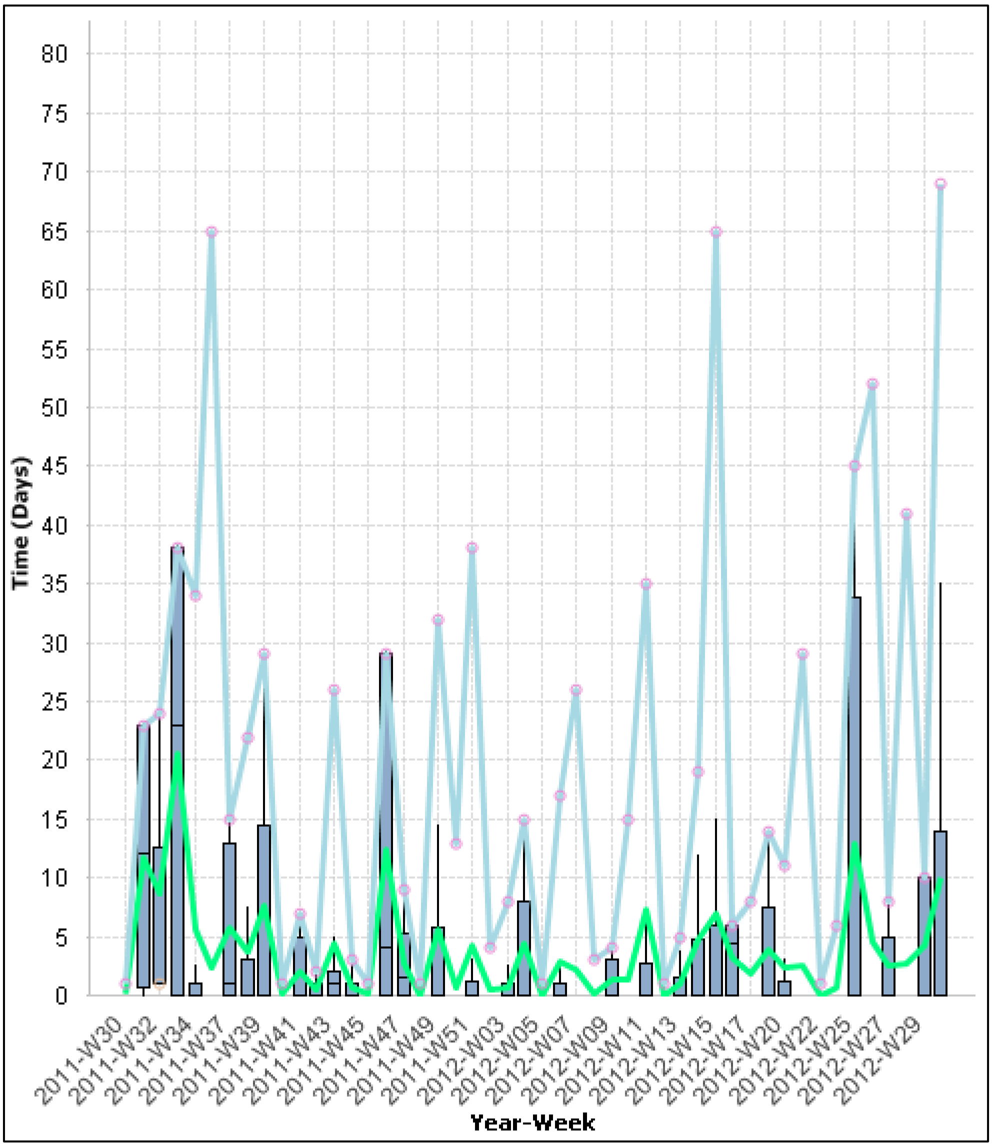

Figure A-60: Boxplot of time in days per week.

Difference between earliest and latest MO material available date

General case

In this measurement the selection material not available as well as CRD as soon as possible has been made. If material was available from the beginning the measurement will be zero. When CRD is realistic the measurement should be as long as possible in some cases, i.e. when some components are in stock and others should be ordered. In those cases less capital is tied up when the ordered component arrive as close to the production start date as possible. This measurements resolution is one second and with these selections 39,9% of all MOs are selected. The average difference is 4,98 days which is acceptable, however not desirable. The variability seen in Figure A-61 is high which indicates that the process is unstable.

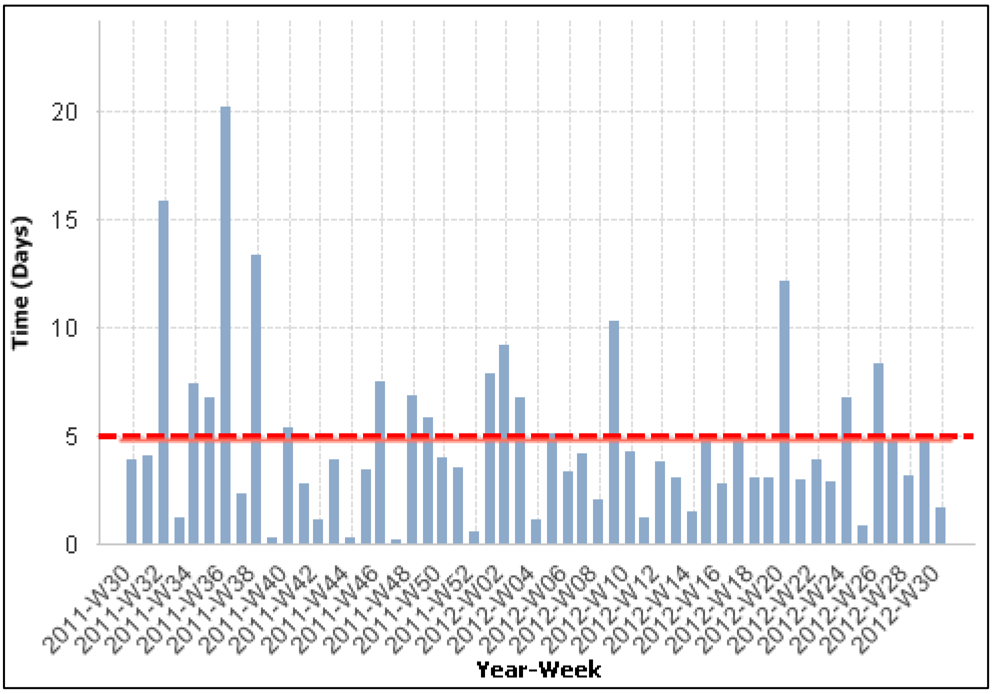

Figure A-61: Average amount of time in days per MO per week.

The distribution can be seen in Figure A-62 where the amount of zero values stand for 65,7% of all values, which is desirable. This means that when material arrives it is synchronized.

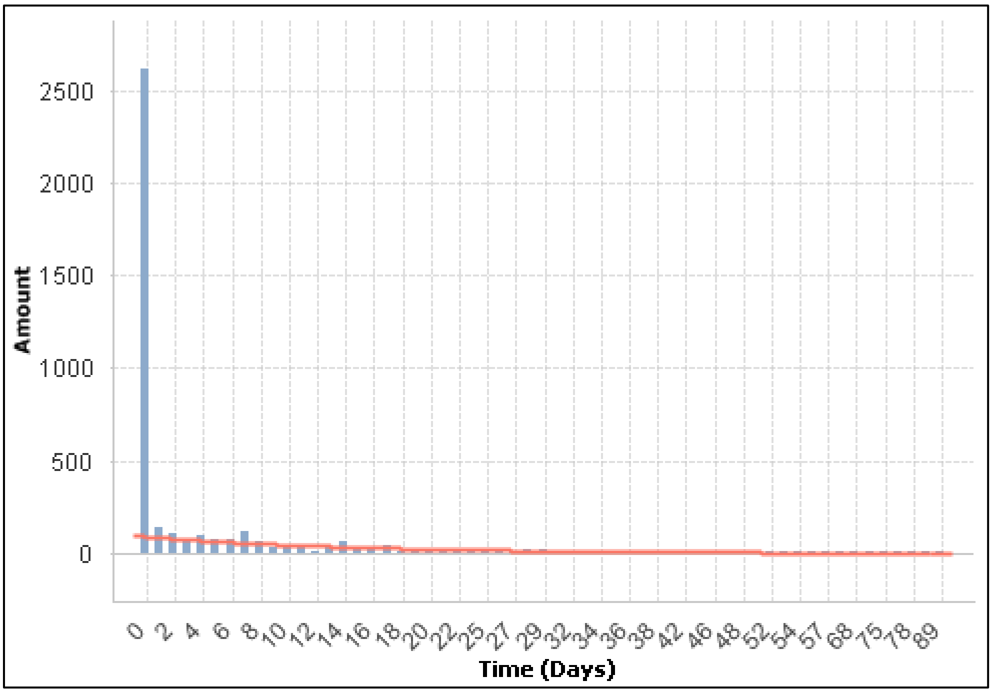

Figure A-62: Distribution of time in days rounded to integer.

The boxplot, Figure A-63, shows a very unstable process. There are many extreme values driving up the average and the boxes are long. The median values are as expected often zero.

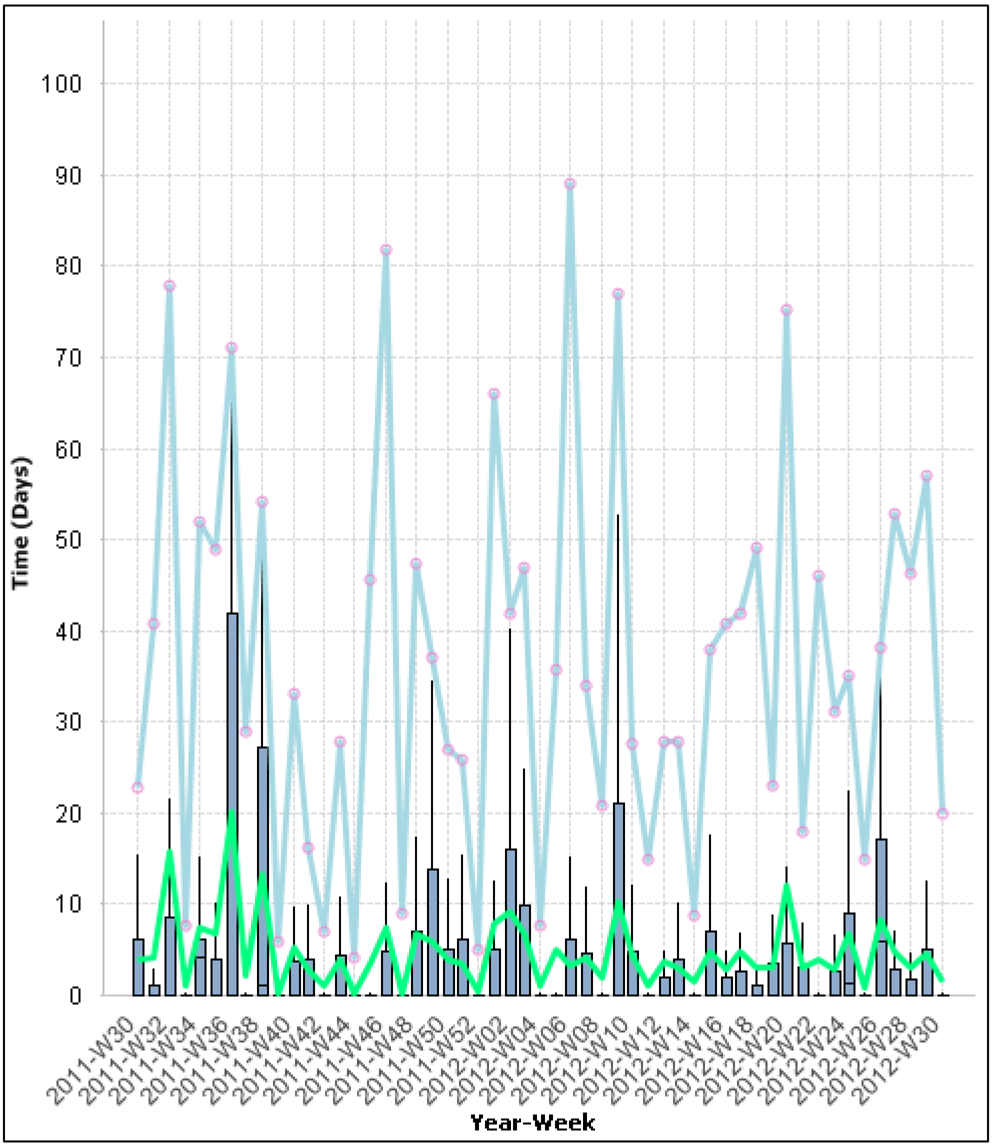

Figure A-63: Boxplot of time in days per week.