Optimizing the supply chain

By creating a new scheduling system

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Preface

The thesis laying in front of you, is my Bachelor thesis “Optimizing the supply chain, by creating a new scheduling system”. The focus of the thesis is based on the creation of a whole new scheduling system to optimize the (internal) supply chain of the company. The thesis is written as final assignment of my study Industrial Engineering and Management at the University of Twente. The assignment is commissioned by Global Electronics B.V. Haaksbergen. I worked on this thesis during a period of 3 months, beginning in April 2018.

I want to thank my supervisor Meino Toering (Global Electronics B.V.) for the useful feedback and for everything I learned from him. Besides, I want to thank my supervisor Jos van Hillegersberg (University of Twente) for his useful feedback as well and our nice chats, I hope we can work together in the future again. Furthermore, I want to thank all of the employees of Global Electronics B.V. for the nice working environment and proper answers on all of my questions. Without them I would not have finished my research project as successful as now.

I hope you will have fun reading my Bachelor thesis.

Wesley Bouwmeester

Enschede, June 26, 2018

Management summary

The research described in this report is executed for the completion of my Bachelor Industrial Engineering and Management at the University of Twente. The research is performed at Global Electronics B.V. in Haaksbergen.

The company already operates for 25 years in the field of electronics with a specification in PCBs for high tech applications. In the last few years, demand increased at a rapid pace which means that supply chain optimization became an important issue within the company. To fulfill the growing demand of the customer, the supply chain should become more efficient than it ever was. During my first meeting with Meino Toering (Managing Director of Global Electronics) it became clear that there were a lot of challenges regarding the optimization of the supply chain. To keep growing and fulfilling the demand of the customer now, and in the future something needed to be changed according to Mr. Toering. This became more clear after I saw the backlog in orders of the company and the poor delivery reliability. A suitable project and big challenge for me as an Industrial Engineering and Management student.

After some research and analysis at the company I stated the following core problem:

'The end date of an order often deviates (too late) with reality'.

With as action problem: 'The current amount of working capital is xx% of the turnover while it should be xx%'.

To try and solve this problem, four research questions are created which are as follows:

RQ1: What are the critical success factors for using LEAN to analyze the problems of processes in a manufacturing company?

RQ2: How are the current processes executed within Global Electronics?

RQ3: Why does the order end date often deviates with reality?

RQ4: How can we ensure that the order end date does not deviate with reality as much as possible?

By answering those four questions a new scheduling system is created which will be described in the next part of this management summary.

We started with the first question which is answered by a systematic literature review. By conducting this review we found the four most important factors for successful using LEAN to analyze problems within a manufacturing company. Those are as follows:

1. It is important to build up a team with experts and the skills needed to be successful in using LEAN.
2. Make use of Value Stream Mapping.
3. It is important to train the right people and first let them learn by doing.
4. Create an organizational culture in which monitoring and controlling is taken into account to use LEAN for analysis in your organization.

Those factors are taken into account by the creation of the new scheduling system and should be taken into account by the management team in the future as well.

Before searching for the actual problems and bottlenecks within the company, a thorough understanding was created by the use of flow charts and Value Stream Mapping. The outcomes of the VSM and flow charts are used as input for the 3rd research question, which will be described in the next paragraph. From the VSM we found the three biggest sources of waste (and the **poor delivery reliability of xx%)** within Global Electronics, which are:

1. Over-production
2. Waiting time
3. Inventory

These forms of waste are created by a lot of different factors from which the most important factors are shown in figure A.

The causes are clustered in different groups which resulted in the choice of 'schedule' to be the biggest problem. We found that there was no schedule at all, so we decided that a whole new scheduling system should be created for the company.

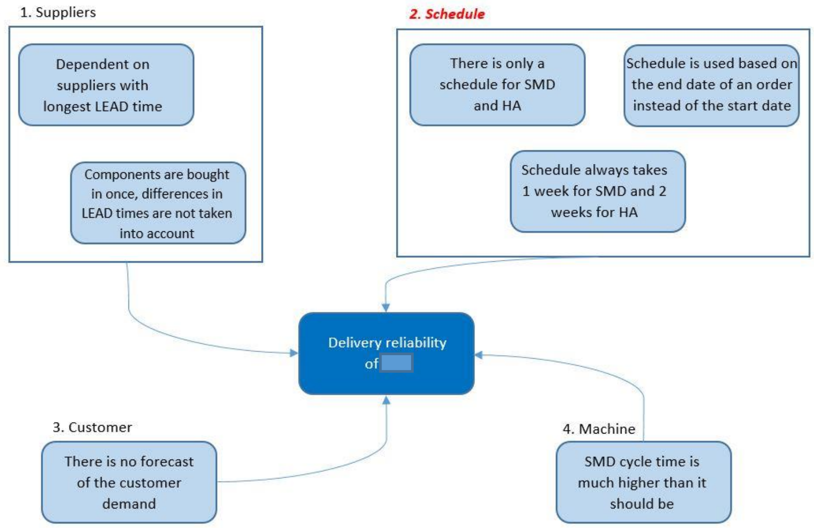

Figure A: Most important causes of waste and poor delivery reliability.

The creation of the new scheduling system should be easy and understandable for everybody. This is why we have chosen to make use of whiteboards and use tags to create a production schedule at every department. This resulted in four new whiteboards, one for every department (three departments) and one in the hallway as an overview board. The input for the boards are the tags which will be scheduled by the use of the 'production schedule' in Excel. A limit should be created on the number of orders, which results in an amount of time, on the whiteboards. In this way a constant number of WIP is created, which results in a big decrease in **over-production**, **waiting time** and **inventory** (the sources of waste we mentioned earlier). As a result the % of working capital of the turnover should decrease as well. As a consequence, more money will be available for investments.

The KPI delivery reliability should be used to measure if the performance of the company increased and also monitor the delivery reliability over time. By measuring the difference between the 'frozen delivery date' and the actual delivery date, which can be exported from Exact (ERP-system).

During my research project my focus was on the improvement of the scheduling system. But, I faced a lot of other points of improvements which could be covered in future projects, which are as follows:

1. **Inventory management**; A challenging project which should face the problem of obsolete stock.
2. **SMD-uptime**; The machines at the SMD department are down half of the time, so use improvements can be made.
3. **HA process**; Hand Assembly takes a lot of time and is one of the bottlenecks within the organization. Starting a project about optimization of the supply chain at HA can result in a lot of time saving.
4. **Starting earlier with the purchase process**; The delivery of components increases the cycle time of an order a lot, again a lot of time saving can be achieved by changing the way of working.
5. Make use of **customer order forecasting** if possible

Glossary/abbreviations

AOI:	Automated Optical Inspection
Bottleneck:	A step in the process which causes the most delay
CT/CTPP:	Cycle Time / Cycle Time Per PCB
ERP:	Enterprise Resource Planning
GE:	Global Electronics
HA:	Hand Assembly
KPI:	Key Performance Indicator
LEAN:	The focus is on eliminating waste
MOQ:	Minimum Order Quantity
PCB:	Printed Circuit Board
SMD:	Surface Mount Device
SME:	Small/Medium Enterprise
Supply chain:	Contains all activities and resources transported between the supplier and the customer
VSM:	Value Stream Map
WIP/CONWIP:	Work In Progress / Constant Work In Progress

1. Introduction

The research that is described in this report is executed for the completion of my Bachelor Industrial Engineering and Management at the University of Twente. The research is performed at Global Electronics B.V. in Haaksbergen. This chapter will introduce the research.

Starting with paragraph 1.1 in which I will give a short explanation of the company. Followed by the context of my research and the problems that I faced. In addition, the research objective and the research questions will be mentioned and I will finish with the stakeholders of my research.

1.1 About Global Electronics

Global Electronics supports their customers in the development of new electronic products. They sustain a high standard, flexible production lines and fast logistic solutions, therefore their engineers work in an efficient way on the production of custom prototypes. According to your preferences Global Electronics can assemble a high quality prototype ready for validation within five days.

Global Electronics always reserves part of their production facility for fast PCB delivery. So, there is always a possibility to create new prototypes or produce and assemble a low volume of PCBs in the short run. The PCB service of Global Electronics consists of assembly, solder and validation of several different components.

Global Electronics likes to take care of everything that the customer wants. This means that the experts of GE give support from the distribution phase until the phase that the final product is created. That is why GE gives a lot of different possibilities, varying from the intake of orders and packaging till inventory management and delivery of the product worldwide.

1.2 Context description

The company already operates for 25 years in the field of electronics with a specification in PCBs for high tech applications. In the last few years, demand increased at a rapid pace which means that supply chain optimization became an important issue within the company. To fulfill the growing demand of the customer, the supply chain should become more efficient than it ever was. During my first meeting with Meino Toering (Managing Director of Global Electronics) it became clear that there were a lot of challenges regarding the optimization of the supply chain. To keep growing and fulfilling the demand of the customer now, and in the future something needed to be changed according to Mr. Toering. This became more clear after I saw the backlog in orders of the company and the poor delivery reliability. A suitable project and big challenge for me as an Industrial Engineering and Management student.

1.3 Problem description

According to (Heerkens & Winden, 2012) there are four different steps to determine your core problem. The first step is to analyze which problems occur within the company. To do this, I went to the company several times to observe the processes on the shop floor and ask questions to the operators. I had also a few meetings with the management team to talk about the current problems and I asked several questions, which resulted in the following problems:

1. **It is hard to make appointments with suppliers:** because the economy grows and grows the demand of raw material also grows and grows. This makes it difficult for SME companies like GE to make good and clear appointments with suppliers, because most of the time GE is not a key partner for the suppliers. Therefore, do the suppliers aim at bigger companies to create their partnerships with.
2. **The ERP-system shows some differences with reality:** sometimes the machines break down because the expected number of components is lower than the systems says. As a consequence, the operator has to gather new components and a lot of time and money is wasted.
3. **There is no production line for the 'Homey':** the 'Homey' is a new product from a Dutch Start-up and they outsource the complete production of the 'Homey' to GE. Because of the lack of a production line there are a lot of inefficiencies.
4. **Forecasting of customer demand is limited:** GE faces some difficulties about the forecasting of the demand of their customers, which makes it difficult to buy the right amount of raw material.
5. **Increasing working capital:** in the beginning of 2018 the working capital increased 42% while the turnover almost stayed the same.
6. **Overview is missing on the shop floor:** it is not clear who has to be in charge of the overview on the shop floor and who are the responsible persons for certain choices. As a result, problems occur within the inventory.
7. **End date of order often deviates with reality.** In the order processing map an end date for every specific order is stated. But often the end date in reality takes more time than determined first.

The second step of the problem identification is about discovering the causes and effects and put them in a problem cluster. In a problem cluster you mention all your problems and define their causal relationship, to determine the core problem.

From this problem cluster I have to determine which of the underlying problems are suitable to set as the core problem for the project. The following problems are going to be tackled by other people:

- Bad agreements with suppliers.
- ERP-system does not match with reality.
- No production line for the Homey
- The overview on the production schedule is missing

So, I do not want to pick these problems as my core problem. Forecasting the customer demand is difficult because there is a lot of variability, so I do not think that this is a suitable core problem for me. This means that there are two choices left to choose as my core problem, namely:

1. End date order often deviates with reality
2. MOQ is often bigger than order requirements.

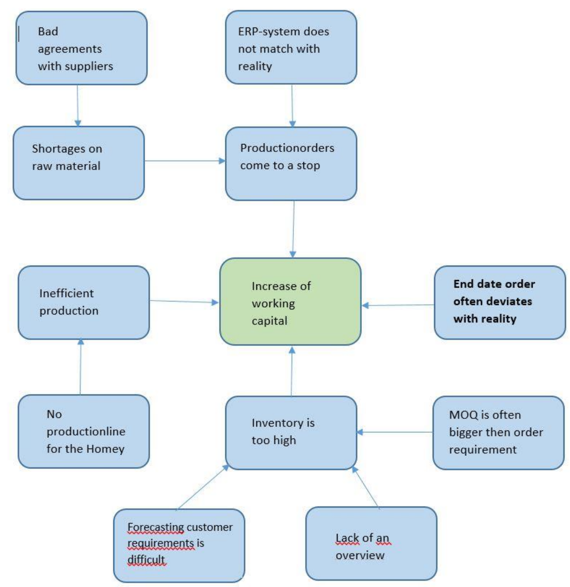

Figure 1.1: Problem cluster

I believe that the first problem has the most influence on the action problem. Because, if orders are always too late this means that the customer gets their orders later than expected. And besides, a lot of processes within the company are not running in an efficient way otherwise the order would be delivered on time. I do not exactly know which are the causes of the core problem, but I believe it is a good starting point for my research.

The core problem I found within the company is stated as follows: **'The end date of an order often deviates with reality'**. Together with the owners and the managers of purchase, selling and production I was assigned to the LEAN management team of Global Electronics. During the several meetings we had so far some of the problems that occur within the company are mentioned, which is shown in the problem cluster. I have chosen the increase of the working capital as the action problem in this project, because all of the different problems with their effects and causes result in this problem. The norm that I want to use is that the working capital should be 12% of the turnover. The reality states that the working capital is 20% of the turnover in the current situation. This results in the following action problem: "The current amount of working capital is 20% of the turnover while it should be 12%."
The **working capital** (in this situation) consists of the following three aspects: the inventory, work-in progress and final products.

1.4 Research objective

The research has two major objectives. First of all, I should come up with ideas, to get orders done more quickly than it is done now and in that way the order end date should not deviate (products should not be finished **after** the delivery date expires) with the end date in reality as much as possible.

Secondly, it is important for me that I learn a lot about the differences between practice and theory. Besides, this is a good opportunity for me to show that I can apply theory in practice and be my own project manager. If I can fulfill both objectives I can look back in a positive way. If I cannot fulfill both objectives I should reflect what went wrong and should be done different/better next time in a same situation.

1.5 Research questions

To solve the core problem of this research I want to answer the following four research questions:

Research question 1: *What are the critical success factors for using LEAN to analyze the problems of processes in a manufacturing company?*

Research question 2: *How are the current processes executed within Global Electronics?*

Research question 3: *Why does the order end date often deviates with reality?*

Research question 4: *How can we ensure that the order end date does not deviate with reality as much as possible?*

1.6 Stakeholders

During my research there are three parties who can benefit from my project.

1. **The management team, including the CEO, manager purchasing, selling and production.**
   The management team faces the biggest problems and have to come up with solutions. They want that the processes in the company are executed in the most efficient and effective way as possible. When this is achieved the working capital will automatically go down and more money is available for other aspects within the company. In the current situation it is not clear which are the root causes of the working capital being too high. Hopefully the management team gets some useful insights with the results of my project. I try to give them the right advise to decrease the working capital as much as possible without other problems to occur.

2. Quality manager (external party)

The quality manager of GE strives for the best quality as possible within the company. The decreasing of the working capital should not have any negative effects on the quality within the company. So with the results of my research project the quality manager can check whether possible solutions does not affect the quality in a negative way. Besides that it is possible that I have some advices which can increase the overall quality within the company. This should be really useful for the quality manager.

3. Operators

Regarding my problem cluster one of the causes of increasing capital is that production orders often break down. This can be very annoying and demotivating for the operators on the shop floor. Possible solutions of my research project can possibly tackle this problem. As a result production orders break down less often which possibly can result in less demotivation of operators. So, it can be possible that the results of my research project enhance the work pleasure of the operators.

2. Theoretical perspective

In this chapter I will describe which theory I will use during the execution of my research. Starting with a short description of the theory itself and following by the tools it includes. Furthermore, I will describe my choice of the theory and the tools that I used during my research. Then I will answer the first research question "What are the critical success factors for using LEAN to analyze the problems of processes in a manufacturing company?" using a systematic literature review. A conclusion will be created and a theoretical model will be presented.

2.1 What is LEAN (synchronization)?

'Synchronization means that the flow of items (materials, information) that constitutes services and products always delivers exactly what customers want (perfect quality), in exact quantities (neither too much nor too little), exactly when needed (not too early or too late), and exactly where required (not to the wrong location). LEAN synchronization is to do all this at the lowest possible cost.' (Brandon-Jones, Johnston, & Slack, 2013)

According to (Jones & Womack, 1996) LEAN manufacturing is defined as a five-step process:

1. Defining the customer value
2. Defining the value stream
3. Making it "flow"
4. "Pulling" from the customer back
5. Striving for excellence

The concepts of LEAN are really helpful during the execution of my Bachelor Project. First of all, because the company itself wants to introduce LEAN in their organization. Secondly, from my own observations and the sessions with the LEAN management team, I am quite sure that points 2, 3 and 4 or not yet fully included into the processes of the company.

To comply with the mentioned principles of LEAN we should consider the different types of waste. Toyota is the company who first identified the seven different types of waste which are applied to many different types of operations in both service and production (Brandon-Jones, Johnston, & Slack, 2013):

1. Over-production. The greatest source of waste is producing more than is immediately needed by the next process in the operation according to Toyota.
2. Waiting time. The efficiency of labour and equipment are two popular measures which are widely used to measure equipment and labour waiting time.
3. Transport. It does not add any value to move your items around the operation.
4. Process. The process itself can be a source of waste as well. Some operations may only exist because of poor component design, or poor maintenance, and therefore could be eliminated.
5. Inventory. All inventory should be considered to be eliminated. However, you can only tackle this waste if you look at the causes.
6. Motion. Sometimes an operator may look busy but there can be no value added by the work. Simplification of work is a rich source of reduction in the waste of motion.
7. Defectives. Quality waste is often very significant in operations.

2.2 Tools for the project

In my own project I want to use one of the tools commonly used in LEAN, namely: 'value stream mapping'. "Value stream mapping is a simple but effective approach to understanding the flow of materials and information as a product or service has value added as it progresses through a process, operation, or supply chain." (Brandon-Jones, Johnston, & Slack, 2013) It gives you a view of a product or services 'production' path from the beginning to the end. In using this it records, not only the direct activities of creating products and services, but also the 'indirect' information systems that support the direct process. "It is called 'value-stream' mapping because it focuses on value-adding activities and distinguishes between value-adding and non-value-adding activities." (Brandon-Jones, Johnston, & Slack, 2013) It is similar to process mapping but different in four ways:

1. It uses a broader range of information than most process maps.
2. It is usually at a higher level (5-10) activities than most process maps.
3. It often has a wider scope, frequently spanning the whole supply chain.
4. It can be used to identify where to focus future improvement activities.

In a value stream you focus on the 'big picture', rather than just optimizing individual processes.

2.3 Why am I using LEAN?

The supply chain of Global Electronics is quite complicated because of several reasons. First of all, they cannot do their whole supply chain with machines and do a lot of manual assembly as well. This means that a part of the supply chain goes 'slow' compared to the other parts which has a big impact on the efficiency and effectivity of the whole supply chain. Secondly, they make a lot of very complicated PCBs and even prototypes which has a big impact on the efficiency and effectivity of the whole supply chain as well. To analyze the exact impact and how efficient and effective they are working, LEAN can be very useful to analyze this problem. Especially the tool Value Stream Mapping which shows where the value is added and where not. Hopefully with the use of this tool the supply chain can be optimized and the efficiency and effectivity increases as a result.

2.4 *What are the critical success factors for using LEAN to analyze the problems of processes in a manufacturing company*?

I want to make use of the concepts of LEAN in my graduation project to solve my action problem. Therefore I want to know which factors are the most important when you want to use LEAN in a manufacturing company to analyze the problems, according to literature. When I can figure this out it will be easier to make use of LEAN during my graduation project.

2.4.1 Critical factors for analysis with LEAN

In the literature of (Liker, 2004), (Achanga, Nelder, Roy, & Shebab, 2006) and (Dumrak, Soltan, & Mostafa, 2013) I found several success factors for using LEAN to analyze the problems in the processes. This is shown in figure 2.1 where I made clusters of factors (different colors) based on similarities of those factors. With this information I want to set up my theory and perform the systematic literature review.

When you want to successfully use LEAN into a manufacturing company you should at least consider the following 4 factors:


(Dumrak, Soltan, & Mostafa, 2013)

1. Expert team building (F1)
2. Situational analysis (F2)
3. Lean communication planning (F3)
4. Training process (F4)
5. Lean tools (F5)
6. Value Stream Mapping (VSM) or Process Mapping (F6)
7. Lessons Learned Review (F7)
8. Lean Assessment (F8)
9. Lean Monitoring and Controlling or Lean Sustaining (F9)

(Liker, 2004)

1. Start with action in the technical system; follow quickly with cultural change
2. Learn by doing first and training second
3. Start with value stream pilots to demonstrate lean as a system and provide a "go see" model
4. Use value stream mapping to develop future stat visions and help "learn to see"
5. Use kaizen workshops to teach and make rapid changes
6. Organize around value streams
7. Make it mandatory
8. A crisis may prompt a lean movement, but may not be necessary to turn a company around
9. Be opportunistic in identifying opportunities for big financial impact
10. Realign metrics with a value stream perspective
11. Build on your company's roots to develop your own way
12. Hire or develop lean leaders and develop a succession system
13. Use experts for teaching and getting quick results

(Shebab, Nelder, Achanga, & Roy, 2006)

1. Leadership and management
2. Financial capabilities
3. Skills and expertise
4. Organizational culture

Figure 2.1: Clustering of critical success

1. It is important to build up a team with experts and the skills needed to be successful in using LEAN.
2. Make use of Value Stream Mapping.
3. It is important to train the right people and first let them learn by doing.
4. Create an organizational culture in which monitoring and controlling is taken into account to use LEAN for analysis in your organization.

2.4.2 Systematic Literature review

In order to execute a systematic literature review I have to start with identifying the key words to use in my search engine. I have to identify my key words based on the theoretical concepts of my knowledge question which is stated in chapter 2.4. In order to identify articles I need to start with the search string which is based on my knowledge question. I tried many different forms of search strings, based on my knowledge question, which results in the following search string: LEAN AND "success factors" AND (compan* OR organization*). To search for articles I make use of the search engine Scopus.

Search string	Search date	Scope	Number of results
LEAN AND "success factors" AND (compan* OR organization*)	25th of march 2018	Article title, abstract, keywords	214

Table 2.1: Searching in Scopus

To filter the most useful articles for my literature review I want to setup my inclusion and exclusion criteria which are found back in the appendix 2.

With the information of tables 2.1, A2.1 (appendix 2, table 1) and A2.2 I want to start with the filtering on articles and search for the most relevant articles to review. The context matrix is shown in table A2.4 in appendix 2, I will now describe the outcomes of the context matrix.

1. It is important to build up a team with experts and the skills needed to be successful in using LEAN.

This is definitely the most critical factor for successful using LEAN for analysis. You can see in my literature review that this factor is a critical success factor in all of the articles. LEAN takes into account a lot of different concepts and tools to use for making your business more successful. So, 'just use LEAN' sounds far more easy than it actually is. All of the use of LEAN starts with a strong team involving members with the right skills. Besides that it is necessary to have experts in your team regarding LEAN, because they know how to deal with all of the different concepts and tools. If you build up this team you have to look for the following set of skills or at least a few of the following skills:

1. Excellent technical knowledge
2. Knowledge of job rules
3. A Kaizen master
4. Leadership skills
5. A good coach

When you build up a team with members that cover all of the mentioned skills the chance of successful using LEAN will become bigger.

2. Make use of Value Stream Mapping

Another important success factor regarding the use of LEAN for analysis is the use of tools that LEAN includes. One of the most useful tools is Value Stream Mapping. With VSM a company can make its value streams visible and therefore the problems will come to the surface. Making use of VSM will therefore make it more easy to see in which processes the company can make the most improvements. So, when you build up a team with experts and the skills needed they should take into account the use of VSM. Besides that this is not the only useful tool, so they should consider other tools (like 5S) as well. "5S is about smart workspace organization ('Good Housekeeping'). Employees are made familiar with the methodology and companies are assisted in the actual realization of a more structured working environment." (Theisens H. C., 2016) In the articles is mentioned that tools are important, but not necessarily only the use of VSM.

3. It is important to train the right people and first let them learn by doing

The third critical success factor mentioned is that training the right people and let them learn by doing is important for successful using LEAN. First of all it is important that they have excellent technical knowledge, which means that they must know the processes involved inside out. This can be achieved by let your employees learn by doing it themselves. This is the responsibility from the management team who should behave as a coach in this situation. After the employees learned by doing the coach should train the employee to get a 'LEAN mindset'. If the people are trained poorly and they did not learn by doing, so they do not understand the processes involved very well. It will be a bigger change that the company fails to successfully implement LEAN.

4. Create an organizational culture in which monitoring and controlling is taken into account to sustain LEAN into your organization

Besides the importance of a team with the right skills and experts it is important that the whole organizational culture is monitoring and controlling all of the different processes to act according to the LEAN principles. It is important that all of the flows and processes are made visible in an easy way. As a result everyone should see whether the processes are running optimally and whether problems occur or not. Whenever a problem occurs it should be visible immediately and people should try to solve the problem as fast as possible. This is only possible when you create the right organizational culture.

I can conclude, based on the systematic literature review, that all of the four factors are indeed critical success factors for successful using LEAN in your organization. If it is possible I want to use these factors in my advice at the end of my graduation project. To give GE useful information about which factors can be critical for the optimization of their current processes.

2.5 Theoretical model

From the Systematic Literature Review, that I performed to answer my first knowledge question, I want to create a theoretical model. During my systematic literature review I reviewed 4 critical success factors regarding the use of LEAN within manufacturing companies.

Factor 4 is the fundamental factor for factors 1 & 2, because you need an organizational culture which inspires their people/employees to make use of LEAN to analyze and improve the processes in the company. Especially in my case it is important to use Value Stream Mapping to map the processes that add value and do not add value to the customer. In this case I am not part of the company but just 'someone from outside', so I do not need the organizational culture to push me to use LEAN. But if I was part of the company this should be the case because I do not think that I would start using LEAN and especially VSM on my own to analyze the processes.

In the literature that I read it is mentioned that LEAN often is used in the wrong way because of a lack of understanding. This is why teams should be built with experts and the skills needed to know exactly how to use LEAN within a company. So, again it should be very important in the organizational culture to create the right teams with the people needed to successfully use LEAN within the company. Again this is not very important in my case because I have to work on my own. This is why factor 1 and factor 2 are dependent on factor 4 which is shown in figure 2.2.
People do not know how to use LEAN without any training and/or trying. When they are thoroughly trained and tried the different concepts of LEAN, they are able to become part of a 'LEAN team'. The training and trying should be provided through the organization itself, so again the organizational culture plays an important role here and is also fundamental for factor 3. So, LEAN teams are dependent on the trained people which is again shown in figure 2.2.

So, if the team works in the right organizational culture, is formed by trained people and makes use of VSM, LEAN can be successfully used to analyze the problems of the processes. Those are not the only four factors, but during the systematic literature review I found that those factors are the most important.

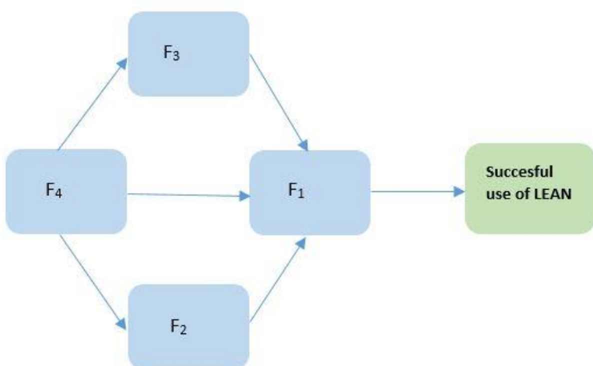

Figure 2.2: Theoretical model

3. Description of the supply chain

In this chapter we answer the second research question, which is mainly used as an input for the 3rd research question. The research question that is answered in this chapter is:

How are the current processes executed within Global Electronics?

To answer this question we will do different things. In section 3.1 the layout of the company will be described. After that, in section 3.2 a flowchart will be shown to display the different processes in a graphical way, furthermore there will be a description of the processes. With these information a Value Stream Map is created to divide the value adding processes from the non-value adding processes. The overall goal of this chapter is to get a thorough understanding of the company and their supply chain. And use this information as an input for the next chapter.

3.1 Layout of the company

The production facility of Global Electronics is not really big. The layout of the ground floor is shown in figure 3.1. There is also a 2nd floor, which contains the test & repair department and some other rooms which are not relevant to mention, because they do not play an important role during my project.

The warehouse is divided in two sides, one side is for the storage of SMD components and the other side is for the storage of HA components. Most of the time there are 2 or 3 workers in the warehouse. In addition, the final check is executed in the warehouse. The SMD department contains two different parts, namely the 'preparation part' and the 'production part'. The production part contains two production lines. The first production line has 5 machines in a row (including inspection), the other production line has 4 machines in a row (excluding inspection) and the 5th one next to it. The preparation part is logically used to do the preparation before production. The hand assembly part contains around 15 workstations which are used for the different hand assembly tasks. The solder room is used by the hand assembly department for some production orders. The work preparation is done in the work preparation office and the AIC next to it is used as a multifunctional room for several different actions. As mentioned earlier the Test & Repair room is located on the 2nd floor. I will be working in the work preparation office, so that I am close to the shop floor to ask questions and do observations for information gathering and analyzing the processes.

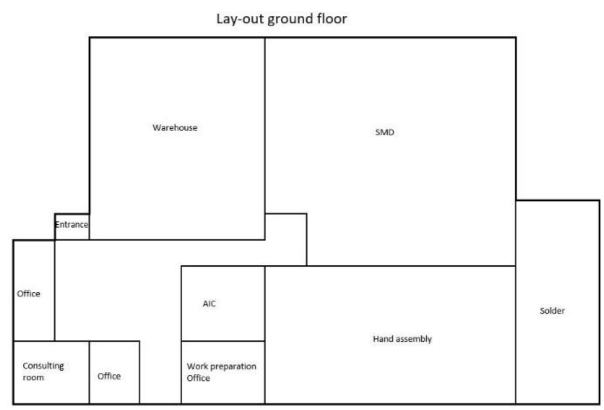

Figure 3.1: Layout of the ground floor of Global Electronics

3.2 Flowcharts and description of processes

Global Electronics is a manufacturing company and does the assembly of PCBs as described earlier. To get a thorough understanding of the supply chain I talked with a lot of people all of them are responsible for a part of the supply chain. With this information I created several flow charts for all of the different parts of the supply chain. From these flow charts I created one for the supply chain in general as shown in figure 3.2.

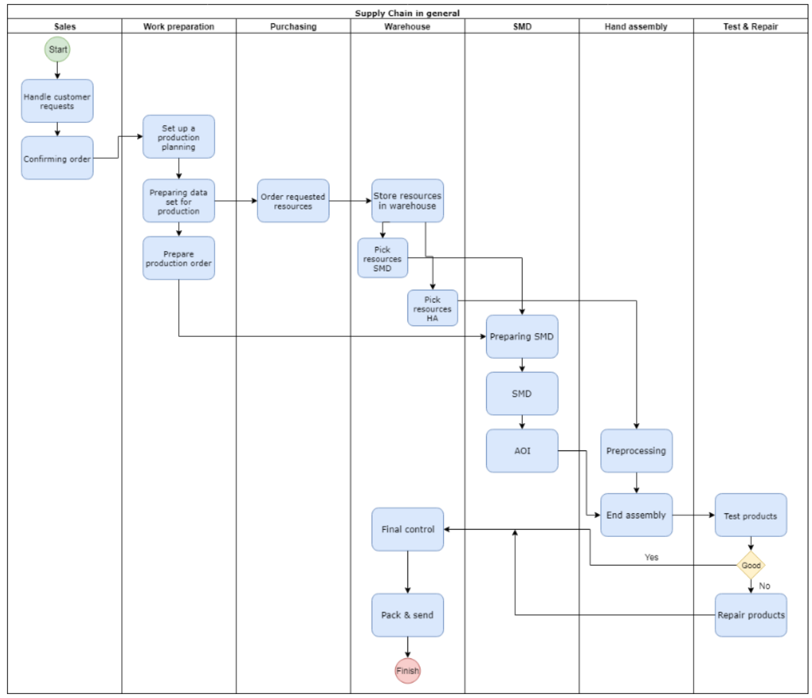

Figure 3.2: Flowchart of the supply chain in general

The sales department is at the beginning of the supply chain. They receive and process the customer requests and in most of the cases the customer accepts the quotation and the work preparation can start. The work preparation department immediately plans the new order and states a start date for the production in combination with an expected delivery date. Afterwards there are several tasks left before the production can actually start. A dataset is created in which all of the project data is included. This is needed for the purchasing department, because they purchase the components and PCBs based on this data. The work preparation department can continue with some of the remaining steps which are, preparing the work instructions and preparing the Pick & Place program for the machines. The only step that cannot be executed is the preparation of the production order, because they are dependent on the suppliers and have to wait until the components arrive. After the components arrive, the warehouse department stores the goods in the warehouse. The components are picked after they are needed for a production order. Most of the time, components for both SMD and HA are needed for the production order. Those goods are picked on separate moments in time, because most of the time HA cannot start before SMD is finished.

After everything is picked and the order progression map arrived at the SMD department they can start preparing the actual production. The roles with components need to be placed into the trolleys before they can be placed into the machines. Furthermore, the pick & place programs should be loaded into the machines and finally the SMD process can start. At the end of the SMD line there is an inspection (AOI) to check whether the PCBs fulfill the requirements or not. Most of the time hand-assembly (HA) is needed, so the PCBs are forwarded to the HA department for further processing. Sometimes components should be preprocessed before they can be placed onto the PCBs. If HA is finished the products will be transported to the Test & Repair department (most of the time). Here they will be tested and if it is necessary they will repair the rejected PCBs before they are forwarded to the warehouse. In the warehouse a final control is executed. If everything is fine and the PCBs fulfill the requirements they will be packed and sent towards the customer.

3.3 Main activities as input for VSM

Value Stream Mapping (VSM) can be explained as follows: "Value stream mapping is a simple but effective approach to understanding the flow of material and information as a product or service has value added as it progresses through a process, operation, or supply chain."

In a value stream you focus on the 'big picture', rather than just optimizing individual processes. Because we will focus on the big picture we have to determine the main activities which are relevant to put into the VSM. Looking at the flow chart created in chapter 3.2, I will use the following activities as an input for my value stream map:

1. WP (work preparation) + Warehouse
2. SMD
3. AOI
4. Hand assembly
5. Test products
6. Final control
7. Pack & send

I have chosen for these activities, because they cover the whole supply chain, they are the higher level activities and they can be used to identify where to focus on for future improvement activities.

3.4 Value Stream Mapping

The goal of my value stream map, is the reduction of cycle time and the elimination of waste. The value stream that I am going to focus on is from single components until delivery of created PCBs for the customer. Before starting with the actual mapping I want to elaborate on the value part, because what is value actually? According to (Theisens H. , Lean practitioner & lean expert, 2017) 'Value' is: "The activities a customer wants to pay for". The activities of a company can be separated in three different groups, namely:

1.	Value adding activities	*Customer wants to pay for it*
2.	Non-Value adding activities	*Customer does not want to pay for it*
3.	Necessary activities	*Necessary for the process*

A company should strive for a culture in which non-value adding activities are eliminated as much as possible and the time spent on necessary activities should be reduced as much as possible. As a result, the value-adding activities will remain and outweigh the non-value adding activities. To be a value-adding activity it should fulfill three different requirements:

1. The customer wants to pay for the activity
2. The activity should be performed the first time right
3. The activity should transform the product in a certain way

Now we know a bit more about what value and a value-adding activity actually is, we can make a start with the VSM. In the VSM we map both the value-adding and non-value adding activities to search for the bottlenecks in the process. For the creation of the value-stream map I want to follow the 9 steps provided by (Theisens H. , Lean practitioner & lean expert, 2017) which are:

- Step 1: Map the customer demand
- Step 2: Map the available work time of the employees
- Step 3: Map the process flow in combination with the inventories
- Step 4: Add the flow of resources between the processes (Push & Pull)
- Step 5: Add data-boxes with information for every process step

- Step 6: Add the information flow
- Step 7: Add the flow of resources and finished products
- Step 8: Add a timeline with waiting time and cycle time
- Step 9: Define the value added and non-value added time to the map

The value stream map is made in a systematic way by following all of the 9 different steps. This resulted in the following Value Stream Map:

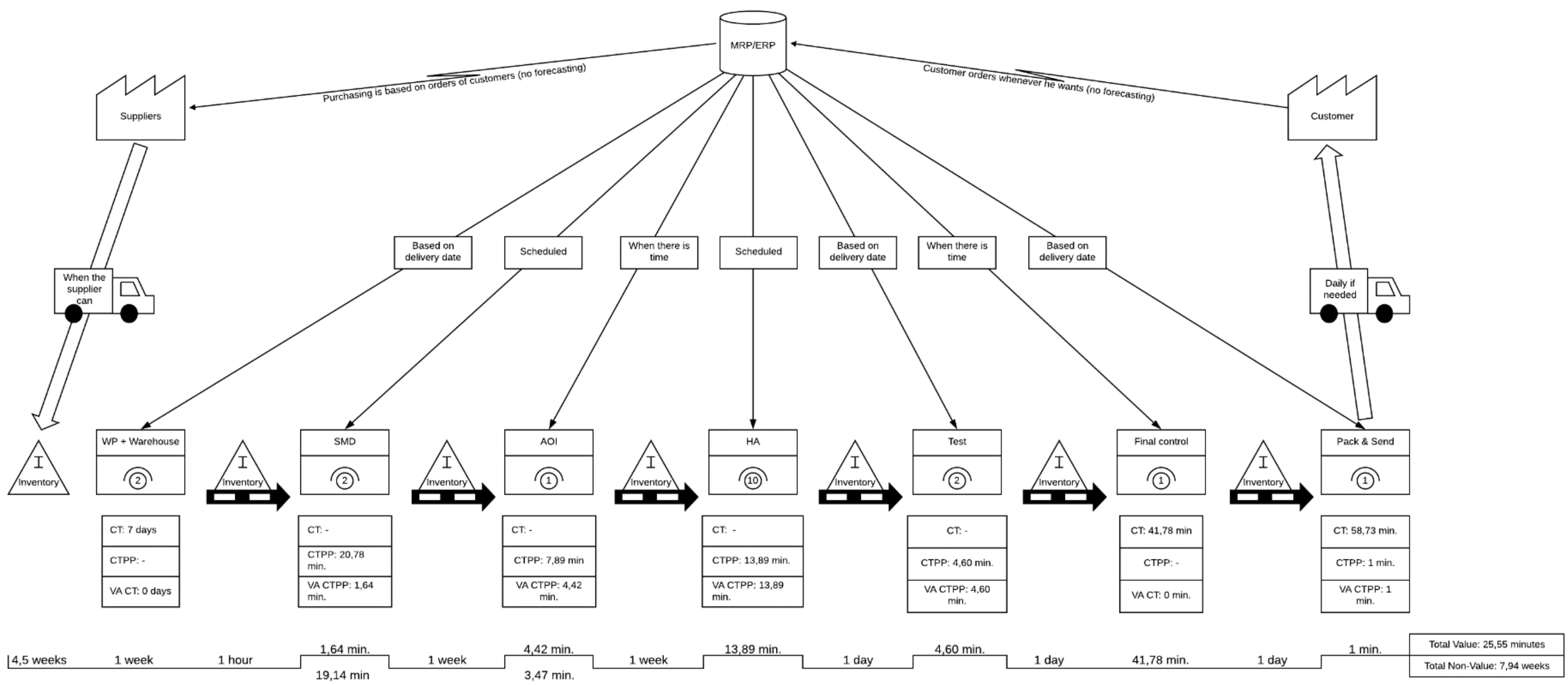

Figure 3.3: Value Stream Map of Global Electronics

The value stream map (figure 3.3) starts in the right top with the customer who orders whenever he wants. Then the information comes into Exact (the ERP-system) and the components can be purchased based on the incoming orders. The supplies are delivered when the supplier can and after a certain moment the components will be placed into the warehouse. From then on the production can start, which is explained in chapter 3.2, on average the end-product will be delivered after 7,65 weeks. Only the SMD and HA production is based on a schedule made by the production manager. WP + Warehouse, Testing and Pack & Send is done based on the delivery date of the end-products. So, the responsible people look when something needs to be delivered (in Exact) and with that in mind they try to assume by themselves when they have to start with their process. AOI and Final Control is done when the responsible people have time for it. In figure 3.4 some other information from the VSM is explained. The different times mentioned in the VSM are based on three different aspects (to increase validity):

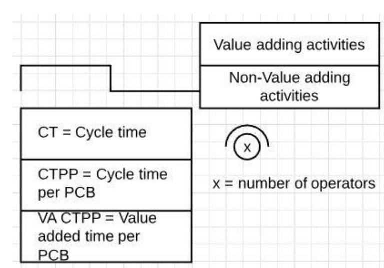

Figure 3.4: Legenda VSM

1. Analysis of historical data
2. Theoretical data
3. Estimations of responsible people

1. Analysis of historical data

On the shop floor the employees work with a 'clock system' which means that they measure the time they spend on a certain step within the production process. These times are registered in Exact and can be exported to Excel whenever you want. This data is used as a main input for the Cycle times and Cycle times per PCB in the VSM. I made use of data from the 1st of January 2018 until 19th of march 2018. I have chosen this time frame, because it gives a good view of the current situation and there are at least 150 measures of each separate step. The historical data is analyzed and visualized by the creation of Boxplots (appendix 4) to search for extreme values and see whether the average gives a good representation of the underlying values. The average values of the Cycle Time and Cycle Time Per PCB are shown in table 3.1. Note that it was not possible to get all of the averages, the reasons will be explained later on in this chapter.

Process step	Average CTPP	Average CT
WP + Warehouse	-	8,63 days
SMD	20,78 min.	-
AOI	7,89 min.	-
HA	13,89 min.	-
Test	4,60 min.	-
Final Control	-	41,78 min.
Pack & Send	-	58,73 min.

Table 3.1: Average CTPP and CT of production steps

2. Theoretical data

For both SMD and HA the production schedules are made, based on theoretical data. The SMD lines include several machines which have a certain production speed. The production speed can be used to calculate how long it takes to create one PCB (CTPP). For HA it works a bit different because there are no machines involved in this production step. In this step the cycle time is based on the number of actions that should be proceeded per PCB. Every action has a time duration which can be summed up to the cycle time and based on that the cycle time per PCB can be calculated.

Theory	Average time
SMD	1,64 min.
HA	16,21 min.

Table 3.2: Theoretical cycle times

I use the times generated by the theoretical data as 'value added time' as shown in table 3.2, because these times are the most ideal times to use. Unfortunately, in practice there are a lot of factors that increase the actual production time which can be seen as 'non-value added time' and waste.

3. Estimations of responsible people

In every production step there are some employees responsible for the successful execution of that certain production step. Most of those people have a lot of experience within the company and a thorough understanding of the certain production steps. So, they also know a lot about the cycle times of the production orders. Therefore, I asked a lot of people to validate my information and make estimations when there is no historical data available e.g. for the waiting times between production steps. The statements made by the employees are documented in appendix 3.

Remarks on Cycle times:

- *The 'CT = 7 days' of WP + Warehouse is based on the estimation of the warehouse manager and the historical data.*
- *For Pack & Send a CTPP of 1 minute is chosen by estimation of me and the warehouse manager.*
- *For HA I have chosen the time in practice as Value Adding cycle time instead of the one in theory, because I believe this one is more accurate.*
- *For AOI the Non-Value adding cycle time is based on the time the AOI machine should be programmed, which is actually a waste of time although it is a necessary activity.*

With the creation of the VSM there where a lot of limitations which can possibly decrease the reliability of the VSM. I will explain my choices regarding those limitations:

1. **Huge difference between production orders.**
   The order quantity, complexity, number of components and production steps are varying a lot between production orders. This made it (almost) impossible for me to look at a group of production orders for more accurate determination of cycle times. Besides, this resulted in a lot of different cycle times between production orders. To face this problem I looked at the big picture and analyzed the data based on boxplots to exclude uncertainties as much as possible. Furthermore, I tried to validate all of the information as mentioned earlier.

2. **Changeover times have a big influence on small orders.**
   In some production orders only 1-10 PCBs are produced in contrast to production orders with 500-1000 PCBs. The changeover times of some production steps do not have a significant difference between those production orders. So, this will only have a big influence on the CTPPs of small orders. I faced this problem by eliminating some really extreme values which had a big influence on the average CTPP. In addition, in the next chapter I am going to research if this changeover time could be a possible bottleneck in the production process.

3. **The 'clock system' has some limitations.**
   The employees keep track of the actual production time of a production step by a so called 'clock system'. The reliability of this clock system should be considered by the production manager, because it has some limitations. If employee x works on production line 1 and then starts a new order on production line 2 it is possible that the running time of the order on production line will stop (according to the clock system) while it is still running. Fortunately, this does not happen all the time, so by taking enough data these insufficiencies should be ruled out for a big part.

4. **For some production steps only the CT is taken.**
   There are two steps in the production process for which it was impossible to calculate the CTPP, which are WP + Warehouse and Final control. The time of those steps are not based on the order size, which makes it impossible to calculate the CTPP. So, for those two steps we just use the CT which has no big influence on the outcomes of the VSM.

5. **The intermediate stock is not added to the VSM.**
   Normally the intermediate stock is added to the VSM. I did not do this in the VSM of Global Electronics because it is barely determinable because of a lack of information from the system. Furthermore, it is not the most important aspect of my research. I know where the intermediate stock is really high compared to the other places in the production process, but I do not know the exact numbers. I believe this will not have a big influence on the outcomes of my research project.

3.5 Conclusion

The goal of this chapter was to get a thorough understanding of how the current processes are executed within Global Electronics. Furthermore, I wanted to map the current processes with the use of flowcharts and Value Stream Mapping. It can be concluded that there are a lot of complex issues which I had to take into account for the creation of the flowcharts and the VSM. But, after all I created a thorough understanding of the processes. The Value Stream Map is the final deliverable of this chapter and will be used as input for the rest of my research. The next step is to search for the bottlenecks within the current processes.

4. Bottlenecks in the current situation

In this chapter we analyze the outcomes of chapter 3 and look **why** the order end date often deviates from reality. I will elaborate on the most important cause of the core problem. The Value Stream Map in combination with answers on questions to the employees and theory of LEAN will be the most important input for this chapter and the answer on the 3rd research question. The 3rd research question is stated as follows:

Why does the order end date often deviates from reality?

4.1 Biggest sources of waste and their causes

In this paragraph the biggest sources of waste will be described in combination with their most important causes.

According to (Jones & Womack, 1996) LEAN manufacturing is defined as a five-step process:

1. Defining the customer value ✓
2. Defining the value stream ✓
3. Making it ‘flow’
4. ‘Pulling’ from the customer back
5. Striving for excellence

The value stream (step 2) is defined in the previous chapter with the use of Value Stream Mapping. Based on this VSM we want to determine which are the biggest wastes (according to LEAN) within the Supply Chain of Global Electronics. From the 7 different types of waste we have chosen the following sources of waste as biggest problem for the company:

1. Over-production
2. Waiting time
3. Inventory

Now we know the biggest sources of waste it is important to describe which causes affect those different sources of waste. Every cause will be combined with their source(s) of waste and after all I will conclude which is the most important cause and should be elaborated more than the others. The causes, derived by own observations on the shop floor and talking with a lot of different employees, are as follows:

- **1. The production process is dependent on the supplier with the longest lead time.**
  Sources of waste: Waiting time and Inventory.
  From the VSM we can conclude that the average delivery time is around 4,5 weeks. The production process can only start after the supplier with the longest lead time delivered their components. As a result, there is a lot of waiting time which costs a lot of money. Furthermore, an inventory is caused by the suppliers who deliver earlier than the supplier with the longest lead time.

- **2. There is only a production schedule for SMD & Hand-assembly.**
  Sources of waste: Over-production, Waiting time and Inventory.
  The next thing that we can conclude from the VSM is that there is only a production schedule for SMD & Hand-assembly. Although there are more production steps then only these two steps. The lack of production schedules for the other steps cause a lot of over-production, waiting time and inventory between the different production steps. Furthermore, there is no tuning between the production schedules of SMD & HA which cause a lot of over-production at SMD which results again in a lot of waiting time and inventory.

- **3. The production is based on the end-date instead of the start-date of a production order.**
  Sources of waste: Waiting time and Inventory.
  The ERP-system creates a start-date for the production steps of SMD and HA. But, most of the time this start-date is not used for the start of production. Instead the end-date is used as a priority for the start of production. This means that the employees look at the end-date of an order and the one with the end-date closest to the current date is started as first. The time and complexity of the different production orders is not taken into account. Again this results in a lot of waiting time and inventory.

- **4. The cycle time of the SMD production line is much higher than it should be.**
  Sources of waste: Waiting time and Inventory.
  In the VSM it is shown that the value added cycle time of SMD is 10 times less than the non-value added cycle time. This means that the machines run very inefficient and a lot of time is wasted during this production step. On average the SMD lines are placing components on the PCBs in 22% of the time, this is based on machine data as shown in figure 4.1. As a result, a lot of waiting time and inventory is created.

Figure 4.1: SMD production line efficiency

- **5. Customer orders whenever he wants and there is no forecasting.**
  Source of waste: Waiting time.
  The customer can order whenever he wants and no forecasts are made. Although it is difficult to forecast the customer demand, because of the high variability, at least it could be tried. If there is time spend on customer forecasting it could be more easy to manage the purchasing and production within the company. Because of a lack of forecasting the waiting time increases.

- **6. All components are purchased at once and the differences in LEAD times are not taken into account.**
  Sources of waste: Waiting time, Inventory.
  In the current situation when an order is confirmed by the customer, the purchasing is done in once. The purchasing is done at a lot of different suppliers, which creates a lot of difference in LEAD times. It can happen that one supplier has a lead time of 6 weeks and the other suppliers have a LEAD time of a few days. As a consequence, the components of the suppliers with a LEAD time of a few days will be stored in the warehouse for a few weeks. This creates a big inventory which costs a lot of money, besides there is a lot of waiting time.

Most of the causes have something to do with the current 'schedule system'. A lot of problems occur because the production is based on the end-date in the production schedule and for some production steps there is no schedule at all. In figure 4.2 it is shown that 3 out of 7 causes (of the poor delivery reliability) have something to do with the current schedule.
So, I decided jointly with my supervisor and the LEAN management team to focus on the 'scheduling system' and try to improve this. By first mapping the current situation and afterwards creating the new (better) situation.

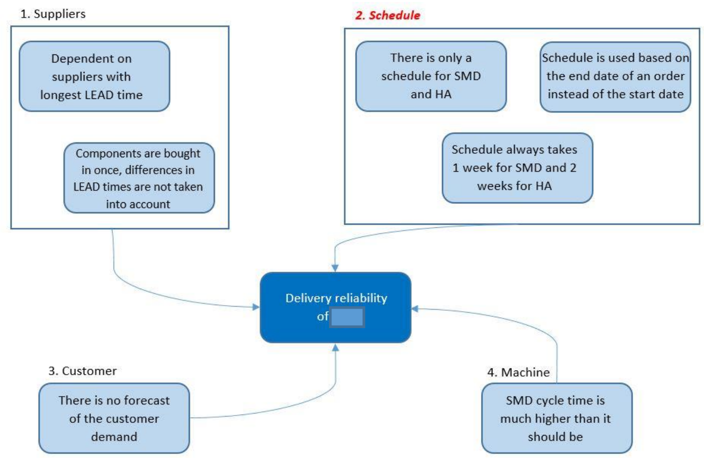

Figure 4.2: Clustering the causes

4.2 Current 'schedule system' mapped through an 'order journey'

In this part the current schedule system will be mapped with a flow chart and an in-depth description to determine the bottlenecks and points of improvement.

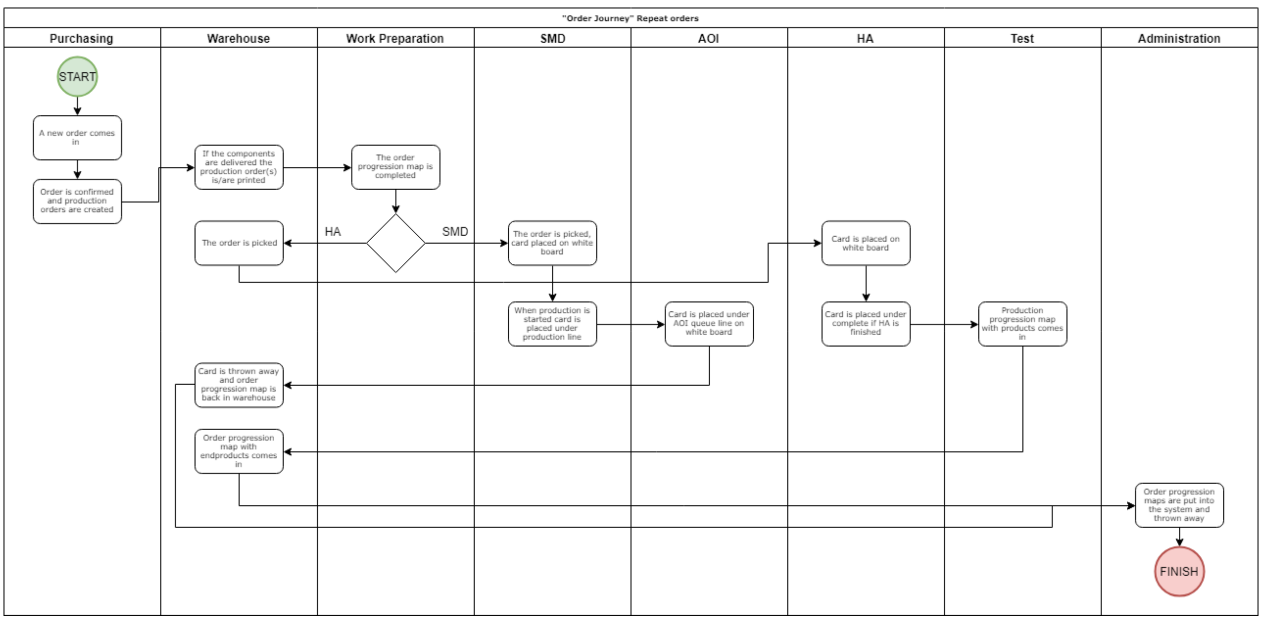

Figure 4.3: Order journey of the order progression maps

The flowchart from figure 4.3 shows the 'order journey' throughout the company and will be followed by an in depth description of the different steps during the 'order journey'. Which is created after following the order throughout the company. After I created this I validated it with the responsible people.

1. Purchasing/Sales

The 'order journey' starts at the purchasing/sales department. They receive the orders of the customers and approve the incoming orders. After that point the production orders are generated automatically in combination with an end date for production, as shown in figure 4.4. This date is based on the delivery date which the customer wants.

After that, the start date is generated based on the cycle time of SMD and Hand assembly, 5 days and 10 days respectively before the product should be delivered. Unfortunately, this start date is not stated on the order progression chart. As a result, the operators on the shop floor do not know exactly when to start with a production order.

07/05 al gepickt.
14/05 VBW.

ORDERVOORTGANGSKAART
PROEFEXEMPLAAR

GLOBAL

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PO: 100000017397

Artikelcode: NZRX88712R7BA 88712R7B RX 410-430 /A

VO: 10005100 Einddatum: 21-05-2018 Aantal: 100,00

Controlepunt *	Aantal *	In-structie *	Partij goedgekeurd *	Paraaf en controledatum *
MAG Magazijn MAG-LABOR		[] Ja [] Nee	[] Ja [] Nee; AMR	
VBW Voorbewerken VBW-LABOR		[] Ja [] Nee	[] Ja [] Nee; AMR	
HMC Handmontage HMC-LABOR		[] Ja [] Nee	[] Ja [] Nee; AMR	
TUP Touch-up TUP-LABOR		[] Ja [] Nee	[] Ja [] Nee; AMR	
EQC Eindcontrole EQC-LABOR		[] Ja [] Nee	[] Ja [] Nee; AMR	
VER Verzenden VER-LABOR		[] Ja [] Nee	[] Ja [] Nee; AMR	

Figure 4.4: Order end-date on production sheet

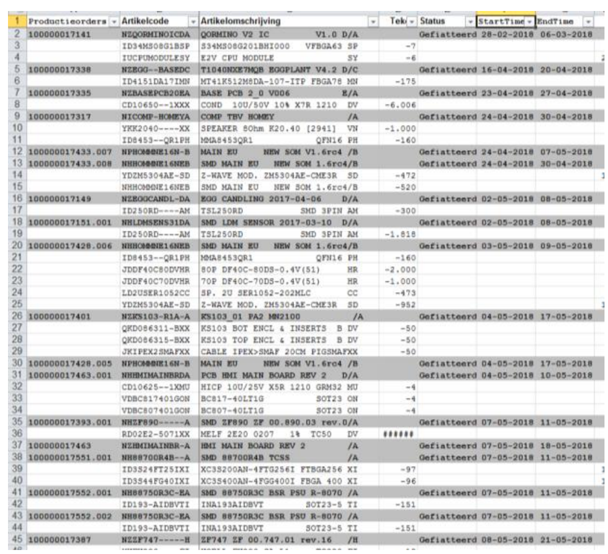
Bottlenecks/problems:

- End-date is used on order progression map and the start-date is not taken into account.
- The cycle time for SMD and Hand assembly are always 5 days and 10 days no matter what.
- The end-date is only based on the requirements of the customer. Although the **production capacity**, **delivery dates of components** and the **size of an order** have a big influence on the delivery date of an order as well, they are not taken into account.

After the production orders are generated and everything is approved they are placed into the ERP-system. An overview in Excel is generated automatically which is used by the Warehouse department to continue with the 'order journey'.

2. Warehouse

After the purchasing/sales department did their job the flow of the order continues at the warehouse. The running production orders are placed into an excel worksheet with a link to Exact (this goes automatically), as shown in figure 4.5. The grey rows are the production orders and the white rows are the components that still need to be delivered for that production order. So, a production order can only be started after the white rows are eliminated. After the white rows are eliminated the warehouse manager decides, based on the start date, whether to start an order or not. If the order is started some papers are printed and brought to the work preparation department. If they are done the order progression map of HA goes back to the warehouse.



1	Productieorders	Artikelcode	Artikelomschrijving	Tek	Status	StartTime	EndTime
2	100000017141	NZQORMINOICDA	QORMINO V2 IC V1.0 D/A		Gefiatteerd	28-02-2018	06-03-2018
3		ID34MS08G1BSP	S34MS08G201BHI000 VFBGA63 SP	-7			
4		IUCPUMODULESY	E2V CPU MODULE SY	-6			
5	100000017338	NZEGG--BASEDC	T1040NXE7MQB EGGPLANT V4.2 D/C		Gefiatteerd	16-04-2018	20-04-2018
6		ID4151DA17IMN	MT41K512M8DA-107-ITP FBGA78 MN	-175			
7	100000017335	NZBASEPCB20EA	BASE PCB 2_0 V006 E/A		Gefiatteerd	23-04-2018	27-04-2018
8		CD10650--1XXX	COND 10U/50V 10% X7R 1210 DV	-6.006			
9	100000017317	NICOMP-HOMEYA	COMP TBV HOMEY /A		Gefiatteerd	24-04-2018	30-04-2018
10		YKK2040----XX	SPEAKER 8Ohm K20.40 [2941] VN	-1.000			
11		ID8453--QR1PH	MMA8453QR1 QFN16 PH	-160			
12	100000017433.007	NPHOMMNE16N-B	MAIN EU NEW SOM V1.6rc4 /B		Gefiatteerd	24-04-2018	07-05-2018
13	100000017433.008	NHHOMMNE16NEB	SMD MAIN EU NEW SOM 1.6rc4/B		Gefiatteerd	24-04-2018	30-04-2018
14		YDZM5304AE-SD	Z-WAVE MOD. ZM5304AE-CME3R SD	-472			
15		NHHOMMNE16NEB	SMD MAIN EU NEW SOM 1.6rc4/B	-520			
16	100000017149	NZEGGCANDL-DA	EGG CANDLING 2017-04-06 D/A		Gefiatteerd	02-05-2018	08-05-2018
17		ID250RD----AM	TSL250RD SMD 3PIN AM	-300			
18	100000017151.001	NHLDMSENS31DA	SMD LDM SENSOR 2017-03-10 D/A		Gefiatteerd	02-05-2018	08-05-2018
19		ID250RD----AM	TSL250RD SMD 3PIN AM	-1.818			
20	100000017428.006	NHHOMMNE16NEB	SMD MAIN EU NEW SOM 1.6rc4/B		Gefiatteerd	03-05-2018	09-05-2018
21		ID8453--QR1PH	MMA8453QR1 QFN16 PH	-160			
22		JDDF40C80DVHR	80P DF40C-80DS-0.4V(51) HR	-2.000			
23		JDDF40C70DVHR	70P DF40C-70DS-0.4V(51) HR	-1.000			
24		LD2USER1052CC	SP. 2U SER1052-202MLC CC	-473			
25		YDZM5304AE-SD	Z-WAVE MOD. ZM5304AE-CME3R SD	-952			
26	100000017401	NZKS103-R1A-A	KS103_01 PA2 MN2100 /A		Gefiatteerd	04-05-2018	17-05-2018
27		QKD086311-BXX	KS103 BOT ENCL & INSERTS B DV	-50			
28		QKD086315-BXX	KS103 TOP ENCL & INSERTS B DV	-50			
29		JKIPEX2SMAFXX	CABLE IPEX>SMAF 20CM PIGSMAFXX	-50			
30	100000017428.005	NPHOMMNE16N-B	MAIN EU NEW SOM V1.6rc4 /B		Gefiatteerd	04-05-2018	17-05-2018
31	100000017463.001	NHHMIMAINBRDA	PCB HMI MAIN BOARD REV 2 D/A		Gefiatteerd	04-05-2018	10-05-2018
32		CD10625--1XMU	HICP 10U/25V X5R 1210 GRM32 MU	-4			
33		VDBC817401GON	BC817-40LT1G SOT23 ON	-4			
34		VDBC807401GON	BC807-40LT1G SOT23 ON	-4			
35	100000017393.001	NHZF890-----A	SMD ZF890 ZF 00.890.03 rev.0/A		Gefiatteerd	07-05-2018	11-05-2018
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38	100000017551.001	NH88700R4B--A	SMD 88700R4B TCSS /A		Gefiatteerd	07-05-2018	11-05-2018
39		ID3S24FT25IXI	XC3S200AN-4FTG256I FTBGA256 XI	-97			
40		ID3S44FG40IXI	XC3S400AN-4FGG400I FBGA 400 XI	-96			
41	100000017552.001	NH88750R3C-EA	SMD 88750R3C BSR PSU R-8070 /A		Gefiatteerd	07-05-2018	11-05-2018
42		ID193-AIDBVTI	INA193AIDBVT SOT23-5 TI	-151			
43	100000017552.002	NH88750R3C-EA	SMD 88750R3C BSR PSU R-8070 /A		Gefiatteerd	07-05-2018	11-05-2018
44		ID193-AIDBVTI	INA193AIDBVT SOT23-5 TI	-151			
45	100000017387	NZZF747-----H	ZF747 ZF 00.747.01 rev.16 /H		Gefiatteerd	08-05-2018	21-05-2018

Figure 4.5: Running production orders

Bottlenecks/problems:

- There are bugs in the excel sheet, so the production orders need to be checked with Exact which takes extra time.
- The start date of a production order does not take into account the delivery date of the components.
- Capacity of the SMD/HA department is not taken into account, so all the production orders can be pushed to the shop floor.

3. Work preparation

The next step in the flow of the production orders is the work preparation. Here, the order progression map is completed and continued to the next department. The map will be forwarded to the SMD department if we have a SMD order and in case of a HA order the map will be forwarded back to the warehouse. There are no bottlenecks within this process as far as I know. Maybe it is possible to **eliminate this step** from the order journey, but this will be determined when a new planning system will be created.

4. SMD

After the work preparation completed their work, the order progression map is forwarded to the SMD department. Here it comes into a box and an order is started based on the end date (figure 4.4). The first step is to pick an order which is done by the warehouse or the SMD operators itself. If this is done the ‘order ticket’ as shown in figure 4.6 comes in the most left lane on the white board. In the current system the ‘order ticket’ contains the production order code and the article code, the number of PCBs is not expressed onto the ticket. Every time a step is finished, the ticket is placed onto the next lane on the white board. Sometimes the production manager prioritizes one order above another one which means that he switches the position of the card on a lane (if there is a queue).

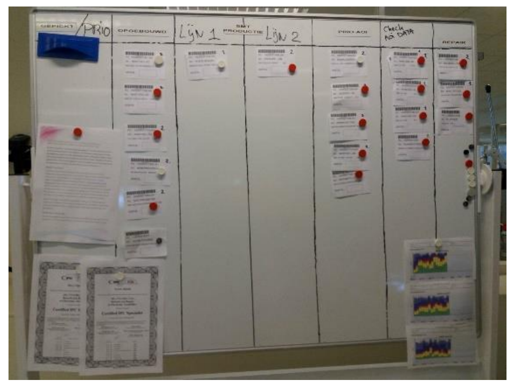


Figure 4.6: Old 'production' whiteboard, used at the SMD department

Bottlenecks/problems:

- Orders are produced based on the end date.
- Orders are pushed into the production line instead of pulled which creates a lot of WIP.
- It is not clear if we are on track or not, the overview is missing.
- The order card can be used a lot better then just putting on the PO code and Art. code.
- There is no tuning between the SMD and HA department.

Figure 4.6: Production order ticket

After the SMD production is finished the production will continue with AOI which is also the next step in the flow of the production order.

5. AOI

The AOI production step is placed on the same whiteboard as the SMD production step. So, after SMD is finished the ‘order ticket’ comes into the queue of the AOI production. The production manager decides which of the orders should be done first and therefore creates the priorities of the different production orders.

Bottlenecks/problems:

- There is no schedule at all for this production step.
- Again a push system is used which creates a big queue and a lot of WIP

After the AOI production step the order ticket is thrown away and the order progression map goes back to the warehouse. A new order progression map in combination with new order tickets are used for the next production steps and flow of the order.

6. HA

If AOI is done and HA is needed the process is continued with HA. A new order progression map is created and brought to the shop floor by the order picker. When the order progression map, in combination with the materials, is brought to the shop floor a new order ticket is placed on another white board as shown in figure 4.7. This is almost the same ticket as shown in figure 4.6, the only difference is that these tickets are foreseen from the size of the order. Again there is no overview and it is definetly not clear from the whiteboard what should be done and if we are on track or not. The production is based on a weekly production consultation on Monday. The manager in the department is the only one with the production schedule and tells the operators what to do and when to do it.

Figure 4.7: 'Production' whiteboard at HA department

Bottlenecks/problems:

- There is a huge amount of WIP which creates a lot of waste.
- It is not clear if we are on track or not, overview is missing.
- Orders are produced based on end date.
- Orders are pushed onto the shop floor.
- Misunderstandings about the completion of an order.

If the HA is completed it is placed onto the most right side of the white board which means done at this department. There were misunderstandings about what this ‘done lane’ exactly meant, because some people thought it meant that the whole order was done. But, most of the time this was not the case, because there is a test step as well.

7. Test

One of the final steps in the order journey is the test step. If orders are completed at HA they are brought to the test department on the 2nd floor, where testing takes place. The order progression map comes along with the PCBs and the order ticket is thrown away. There is no production schedule at all for the test department and the work is pushed towards the test department by the HA department.

Bottlenecks/problems:

- No production schedule.
- HA pushes the work towards the test department.
- There is no good idea on how much work they get during the week.

8. Finish order

If testing is done the order progression map goes back to the warehouse where the final control is done. The final control does not take a lot of time and is done immediately (most of the time). In the warehouse everything is checked before the order progression map is forwarded to the administration department. Here, the administration is done and the order progression maps are scanned and stored into the system. After this is done the order is completed and the customer is delivered. Finishing the order does not obtain any big problems/bottlenecks.

4.3 Conclusion

To answer the research question: "Why does the order end date often deviates from reality?" we took several steps. We started by mentioning several causes which have a lot of (bad) influence on the LEAD time of an order. From these causes we have chosen the current scheduling system as biggest bottleneck. To improve the scheduling system we started with creating a thorough understanding of the current system by creating an 'order journey'. To get insights about the limitations of the current system the 'order journey' is described in combination with the bottlenecks/problems of every step. This resulted in the following list (see bottlenecks/problems in paragraph 4.2) of factors/limitations which should be taken into account during the creation of a new scheduling system:

1. The current scheduling system uses the end date as indicator for the start of the production.
2. The end date only takes into account the end date of the customer although the **production capacity**, **delivery dates of components** and the **size of an order** have a big influence on the delivery date as well.
3. Orders are **pushed** onto the shop floor which creates a lot of WIP.
4. Some production steps do not have a production schedule.
5. There is no tuning between the SMD and HA department.
6. There is a lack of an overview
7. The whiteboards and 'order tickets' can be used a lot better
8. The cycle time for SMD and Hand assembly are always 5 days and 10 days resp. according to the system. While this is not the case in practice.

Taking into account these factors and trying to come up with improvements/solutions will result in a better scheduling system. Besides, the **delivery reliability will increase** and the **number of orders (WIP) on the shop floor will decrease**. Which will be described in the next chapter.

5. New scheduling system

We use the outcomes of chapter 4 as input for this chapter and are looking **how** we can ensure that the order end date does not deviate as much as possible from reality anymore. I will try to come up with a whole new scheduling system based on LEAN tools and techniques. This will result in an advice and answer on my 4th research question which is stated as follows:

How can we ensure that the order end date does not deviate from reality as much as possible?

5.1 Why is the focus on 'pull' and 'flow'

In this paragraph we will describe why we want to focus on 'pull' and 'flow' in the new scheduling system. As described earlier in the approach for a new scheduling system we want to use LEAN principles and tools. According to (Jones & Womack, 1996) LEAN manufacturing is defined as a five-step process:

1. Defining the customer value ✓
2. Defining the value stream ✓
3. **Making it 'flow'**
4. **'Pulling' from the customer back**
5. Striving for excellence

We already defined the value stream with the use of value stream mapping and used this to search for the bottlenecks in the current processes. Now we know the bottlenecks we have to think of a way to improve the current scheduling system by **creating flow** and **adapt from push to pull**. So, why should we create flow? We want to use LEAN to improve the current processes (especially the delivery reliability) in which flow is an important aspect. The focus of LEAN is on getting the right things to the right place, at the right time, in the right quantity, to achieve perfect flow. (Theisens H. , Lean Six Sigma Black Belt Mindset, Skill set and Tool set, 2016) If there is a perfect flow within an organization without interruptions, there is *no or only a little amount of inventory* between process steps. As a result we create a *lower risk off confusion and mistakes*. Besides, flow will create a continuous process to *get the problems to the surface*. Each problem becomes an opportunity for improvement.

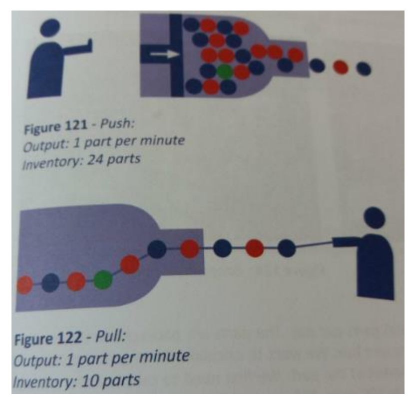


Figure 5.1: Push vs Pull

Besides creating flow, we want to adapt the current scheduling system from push to pull. But, why should we change from push to pull?
What happens now is that every operation produces the amount of parts that it is capable of without alignment of the amounts needed by other processes. As a result, a chaos is created with huge piles of parts around the machines and workstations. These piles are pushed to the next process step in order to create space. Increasing the efficiency of just one single machine, for example SMD, will increase this chaos even more. It will result in excessive quantities of raw materials and semi-finished products.
The push system is created by operation managers who are focusing on optimizing individual process steps or equipment especially when it concerns expensive equipment. (Theisens H. , Lean Six Sigma Black Belt Mindset, Skill set and Tool set, 2016) A backlog in the delivery process results in push behavior, as well because new orders are pushed into the operational process. Push results in overproduction of (semi-) finished products which is seen as a source of waste according to LEAN principles. To avoid overproduction, it is necessary to work according the 'Just in Time' (JIT) principle. This can be achieved by supplying each operation step in the process with the right part, at the right time, in the right volume. To achieve this we should implement pull. Working according pull instead of push will avoid inventory and overproduction.

Starting with the demand of the customer who is the first who pulls. ‘Pull means that the subsequent process determines the number of items that needs to be delivered by the downstream process.’

In table 5.1 we show the differences between a Push and a Pull system based on (Plex, 2017) and (Theisens H. , Lean Six Sigma Black Belt Mindset, Skill set and Tool set, 2016).

Push	Pull
1. A lot of Work-In-Progress	Little Work-In-Progress
2. Creates waste	Eliminates waste *-> Overproduction, waiting time and inventory*
3. “Firefighting”	Solving the real problem
4. Bad communication	Good communication
5. No overview	There is overview
6. High cycle time	Low cycle time
7. Focus on starting	Focus on finishing

Table 5.1: Push vs Pull

1. A lot of Work-In-Progress vs. Little Work-In-Progress

Changing from Push to Pull will make a big difference in WIP on the shop floor. Because, there is a limit on the number of orders for every department and orders are no longer pushed onto the shop floor randomly. Therefore, a lot of money will be saved which can be used for other resources.

2. Creates waste vs. Eliminates waste

A pull system is focused on the elimination of waste in contrast to a pull system which creates waste. The most important elimination is overproduction, which results in an elimination of waiting time and inventory as well.

3. ‘Firefighting’ vs Solving the real problem

In a push system we see a lot of ‘firefighting’ which means that the we do not search for the real problem with his root cause. For example, hiring extra people when you have a backlog in the delivery of the orders. The backlog is caused by something, but in the case of ‘firefighting’ we do not search for the real problem with his root cause, but just hire some extra people. In a pull system the real problems come to the surface and should be solved, otherwise bigger problems occur. This results in a system where continuous improvement is included and the overall supply chain will become more and more LEAN over time.

4. Bad communication vs. Good communication

There is also no communication in a push system between the different work stations. For example, in Global Electronics there are several ‘islands’ which have a bad or almost no communication between each other. So, the warehouse just does their work and does not take into account the next step in the production process. If SMD (next step after warehouse) is very busy it can be the case that new orders come in from the warehouse. In a pull system there is more communication between the different departments which should avoid that the described example occurs again.

5. No overview vs. Overview

In a pull system there is an overview on the shop floor which tells immediately if we are on track or not. Most of the time there is a lack of an overview in a push system which creates a chaos. Furthermore, it creates an uncomfortable working environment for the employees on the shop floor.

6. High cycle time vs. Low cycle time

In a push system there is a lot of waiting time because queues are created. This results in a high cycle time per production order. In a pull system these queues are minimized and an order can go much faster from one work station to another workstation, which decreases the cycle time of an order.

7. Focus on starting vs. focus on finishing

In a push system the focus will be on starting an order instead of finishing. So, a lot of people work on a lot of orders on the same time instead of working on a few orders, which should decrease the finishing speed.

Focus on starting can lead to an excessive inventory, compared to a focus on finishing which will be explained by an example.

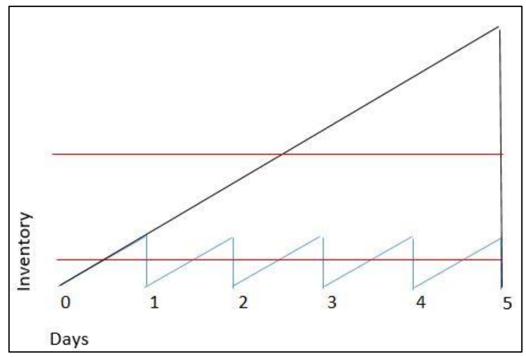


Figure 5.2: Average inventory

Imagine having 5 orders which take 5 days each and we have 5 workers available to work on the orders. If the focus would be on starting all the orders at day 0 and every worker will work on a single order, this results in 5 orders to be finished on the 5th day (black line in figure 5.2). If the focus would be on finishing one order, which will be started on day 0 and all workers will be working on one order, this will result in a finished order every day (blue line figure 5.2). The red lines show the average inventory, the lower one yields for a pull system and the upper one will yield for a push system. We can conclude that a push system (focus on starting) results in a 5 time as high (average) inventory as a pull system according to this example.

We can conclude that a pull system has many advantages compared to a push system and that it is important to create flow. If we are able to put the focus on pull and flow, the delivery reliability should become higher than it is within the current situation. But, pull can only be introduced to a balanced company without a lot of problems, which is not the case yet within Global Electronics.

5.2 How can we focus on ‘pull’ and ‘flow’

In this paragraph we will describe how we can put the focus on pull and flow which will result in a new scheduling system. To get the focus on pull and flow we will introduce the **‘Kanban planning schedule’**.

“Kanban is a simple way to organize your work and to focus on the most value adding tasks. Kanban prevents being very busy without booking any results” (Greaves & Laing, 2018) The most important principles are:

1. Visualize your work
2. Limit the amount of Work-In-Progress and create a system in which team members can pull the work instead of pushing it
3. Create flow
4. Make explicit appointments
5. Improve together as a team

Taking into account these principles results in the new scheduling system as shown in figure 5.3. We will first describe the system and then describe how the 5 principles come back into the system.

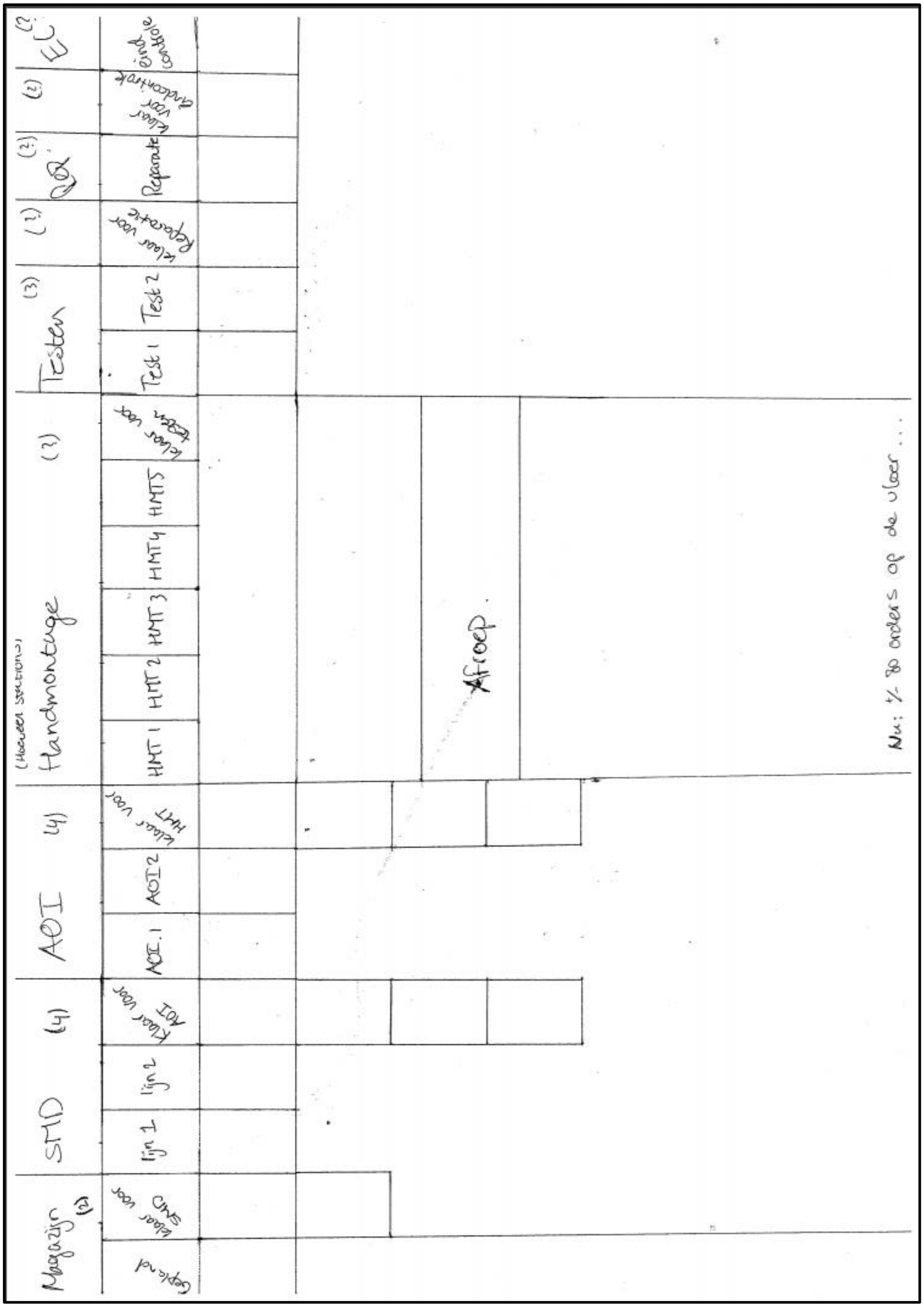
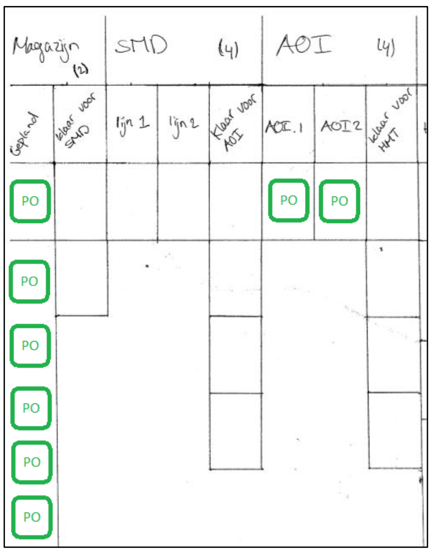


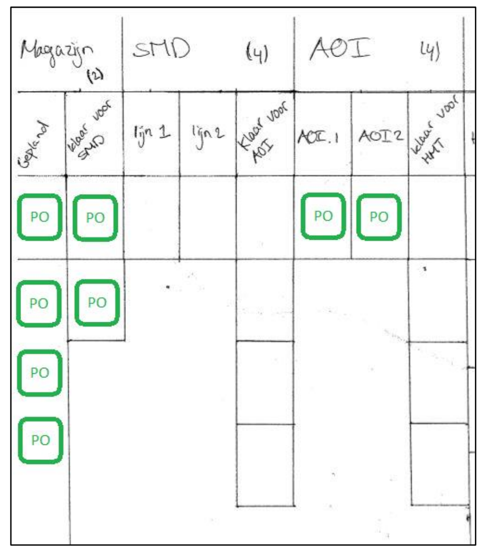
Figure 5.3: Pull scheduling system idea

The template as shown in figure 5.3 should be expressed on a white board which will be placed on a strategic point on the shop floor. All of the different production steps are illustrated onto the new scheduling system and additionally the warehouse is added. Production orders are expressed on tickets which can be placed in the boxes on the whiteboard. The planned production orders are placed on the left side of the white board. There will be a limit on the number of orders that can be picked in the warehouse which is shown under 'ready for SMD'. Every department will have a limit on the number of orders allowed in the department, which should be determined by trial and error.
If the limit of a department is not reached yet and there is an empty production step in a department, the employee can **pull** a production order from an earlier production step. Which will be demonstrated in the example below. We took the first 3 steps of the scheduling system and we assume that the production orders at AOI do not finish during this example.

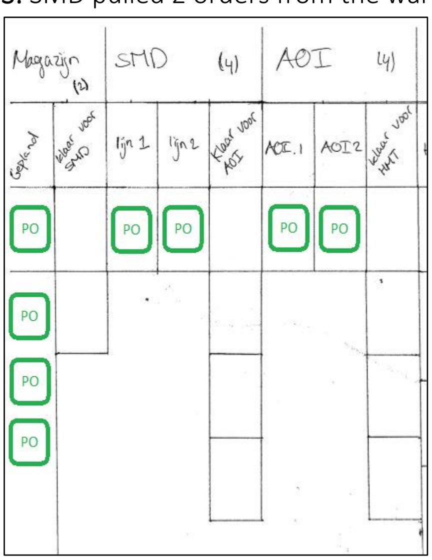
1. Starting situation



2. 2 orders are ready for SMD

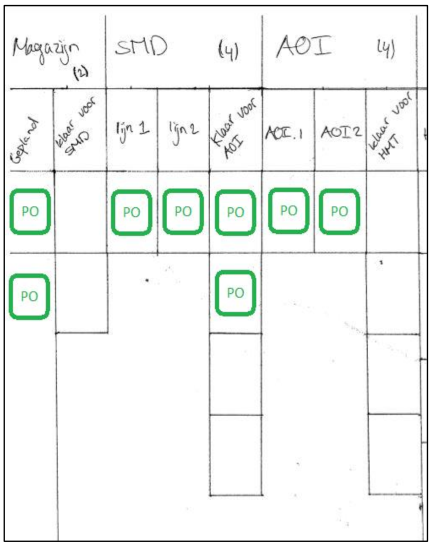


3. SMD pulled 2 orders from the warehouse



4. 2 orders are ready for SMD again

5. 2 orders of SMD are finished and ready for AOI, and SMD pulled 2 orders from the warehouse again



6. Another order from SMD is finished, but the limit is reached, so the machine will stop and no orders can be pulled anymore (bottleneck found)

In the 6th step of the example the limit is reached and now the operators have to realize that they found a bottleneck. If they continue with producing at the SMD line the queue for AOI will become bigger and bigger, which we want to avoid because of the waste it creates. Instead, the operators of line 1 can search for ways to decrease the cycle time at AOI and create more flow. If this is done every time a bottleneck is found we can improve the supply chain on a regular basis.

We will now explain how the 5 principles of Kanban are covered in the scheduling system:

1. *Visualize your work.*

The planning system is expressed on a whiteboard, so that everybody can see in a blink of an eye how we are doing. You can see if we are on track, where the bottlenecks are and how much work there is left for a certain time period.

2. *Limit the amount of Work-In-Progress and create a system in which team members can pull the work instead of pushing it.*

Those two concepts are explained in the example above. Limits are created and the different departments can pull work to their workstations if they have time and space.

3. *Create flow.*

Flow is created because we made one planning system of the whole (intern) supply chain. Besides bottlenecks need to be tackled to make the flow smoother over time.

4. *Make explicit appointments.*

Appointments need to be made about the limits in each of the department. If the operators do not adhere to the appointments the system will not work and we are back at the beginning. Furthermore, appointments need to be made about how to improve and tackle the bottlenecks, which is the next principle.

5. *Improve together as a team.*

Once the bottlenecks are found there should be teams who tackle them and improve the supply chain by themselves. This is one of the biggest challenges of the whole system, because people need to be trained and triggered in the right way. A lot of people have an 8 to 5 mentality and just want to do their work without improving the processes.

We can conclude that we covered most of the principles of Kanban and created a system that could possibly work. But, it is not that easy, because the system contains a lot of challenges before we can actually implement it. Those challenges will be covered in the next part of this chapter.

5.3 Challenges during the implementation of the new planning system

If we want to implement the new scheduling system we face several challenges which should be tackled before we start with the actual implementation. We derived the challenges during LEAN meetings and with own observations. Those challenges are as follows:

1. Some of the employees are not open to change.
2. Most of the employees do not come up with solutions for the bottlenecks, because they are not triggered. (One of the goals of the system is to face the bottlenecks and tackle them)
3. SMD and HA are two completely different production steps, which should be covered in the planning system in a suitable way.
4. The current WIP status should be diminished before we can implement the scheduling system or we should figure out how we can implement the system with the current WIP.
5. Policies and limits (on the amount of WIP) should be created.

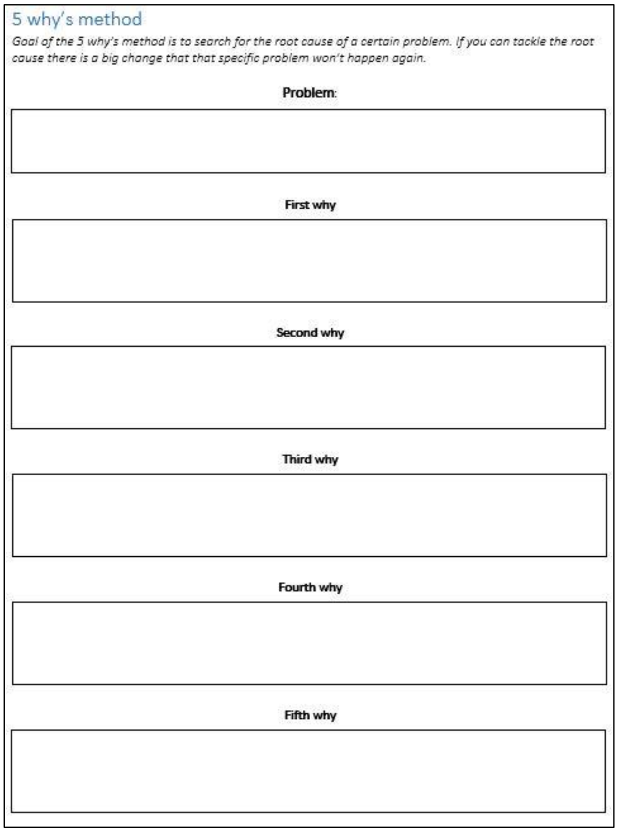
We will now explain how we want to tackle those challenges to come up with a successful implementation of the proposed system, explained in chapter 5.2.

- **Some employees are not open to change.**

If we want the employees to change their current working rhythm (which is the same since 25 years) we should use good communication. It should be clear for the employees why we do what we do, what we expect from them and what it means for them if we are going to use the new scheduling system. This should be done by an explanation of the system to the responsible people of the different departments. Besides, we should organize a meeting with the whole team and ask whether everybody is fine with the new system or not. In case the employees do not agree with the new system, they should come up with suggestions for improvement, so that we can improve the system and make it suitable for everybody.

- **Most of the employees do not come up with solutions for the bottlenecks, because they are not triggered. (One of the goals of the planning system is to face the bottlenecks and tackle them).**

We can introduce the 5 why's method to the employees which has the goal to search for the root cause of a problem. If you find the root cause and you can solve that cause from happening again, the problem will probably do not happen again. To trigger the employees to use this method a reward system should be created. One example is to introduce 'the employee of the month' and give a small present to the winner of the price. I think it is really important to use a reward system, because in this organization people will not come up with solutions/improvements by themselves. Probably they do when they can get a reward.


5 why's method

Goal of the 5 why's method is to search for the root cause of a certain problem. If you can tackle the root cause there is a big change that that specific problem won't happen again.

Problem:

First why

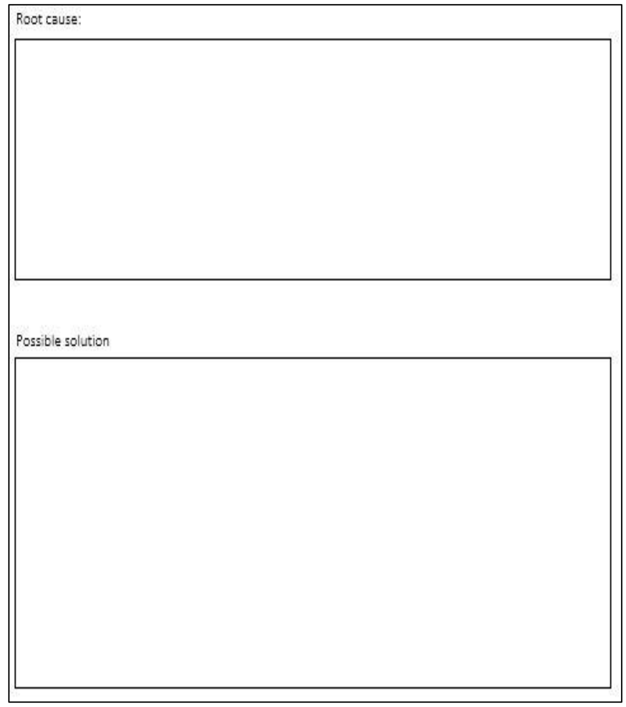
Second why

Third why

Fourth why

Fifth why

Figure 5.4: Searching for the root cause


Root cause:

Possible solution

Figure 5.5: Root cause and possible solution format

2 pages with the information as showed in figure 5.4 and 5.5 should be added to the order progression map which goes along with the production order on the shop floor. Whenever a problem occurs they can fill in the form and at the end the forms will be collected. Once a week the management team or one specific person can analyze the results and implement the possible solution or not. The forms should be used as input for the reward system.

- The current WIP status should be diminished before we can implement the planning system or we should figure out how we can implement the planning system with the current WIP.

After I presented the pull scheduling system to the management team we came to the conclusion that the idea of the system was good, but does not work in the current situation because there is too much WIP. It can be used in the future (probably with some alterations), but first I had to come up with a system that can be introduced immediately. This system will be described now and I will explain how the earlier explained system can be used in the future (with some small alterations).

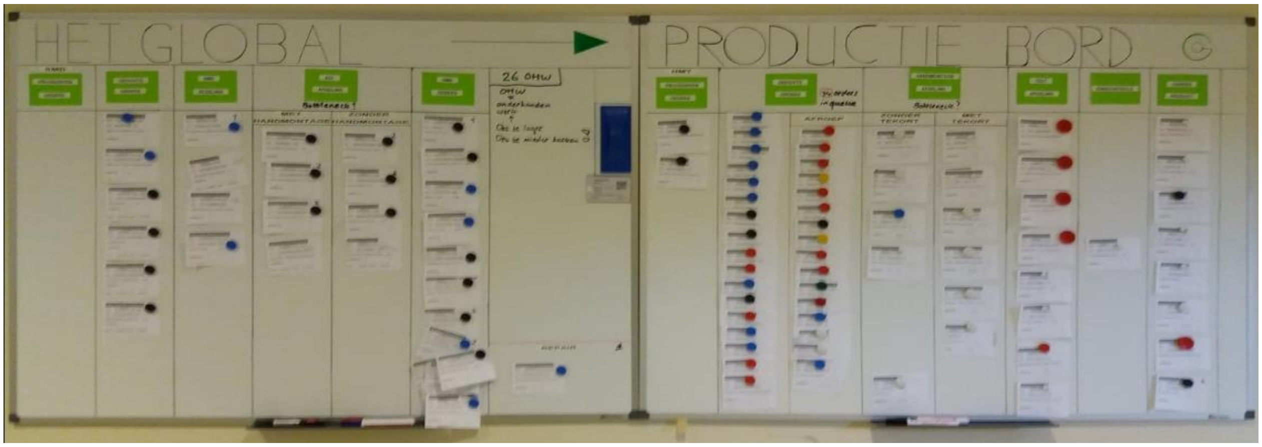


Figure 5.6: The new overview board

I created a completely new 'production board' which is shown in figure 5.6. The goal of the board is to create overview and insights within the whole company. All production orders which are on the shop floor are expressed on this board.
The left whiteboard expresses all the orders which are going through the SMD production line and are undergoing AOI. The right whiteboard expresses all the orders which are going through the hand assembly department and, most of the time, the test department. Both processes have their own 'production order ticket' as shown earlier in chapter 4.

In the most left column we express the orders which can start with the production on the SMD line (after some other steps are taken). The second column contains all the orders which are picked in the warehouse and ready to be prepared. If the orders are prepared to go onto the SMD line they will be moved to the third column. The 4th and 5th column express the AOI production step and we made a distinction between production orders with hand assembly and production orders without hand assembly. If the orders are in the last column they are done at the SMD/AOI department.

In the most left column of the second whiteboard we express again the orders which can start production, but this time it is the hand assembly production. Then again we have the picked orders, now in column 2 and 3, column 3 is added, because we want to make a distinction between normal picked orders and picked orders who will be made when the customer calls (one batch is made and the customer calls for parts of this batch). The 4th and 5th column contain the orders on which the employees are working and here we have a difference between orders who can be made completely and orders with a shortage. The next step is the test department and then we have left the final control (7th column) and the 8th column with the complete product and shipment of it.

The three departments (SMD/AOI, Hand assembly and testing) have their own whiteboards. The goal of those whiteboards is to show the details of each production order and they will be used (in the future) as new scheduling system. I will elaborate a bit on each of the three whiteboards starting with the SMD/AOI whiteboard.

They already had a whiteboard at the SMD/AOI department as mentioned in chapter 4, so I do not want to talk too much about it. The only (very) important column that I added is the most left one which will be used when we start with the new scheduling system. The 'scheduler' will put the work for one week in this column every week to create 'conwip' which means continually work in progress. The scheduler can prioritize the work and determine which orders should be produced first by placing them on top of the column. If the work is placed in the column the employees can **pull** the work to their workplace and as a result the cycle time should be decreased and the delivery reliability should be increased.

Figure 5.7: Scheduling board for SMD/AOI

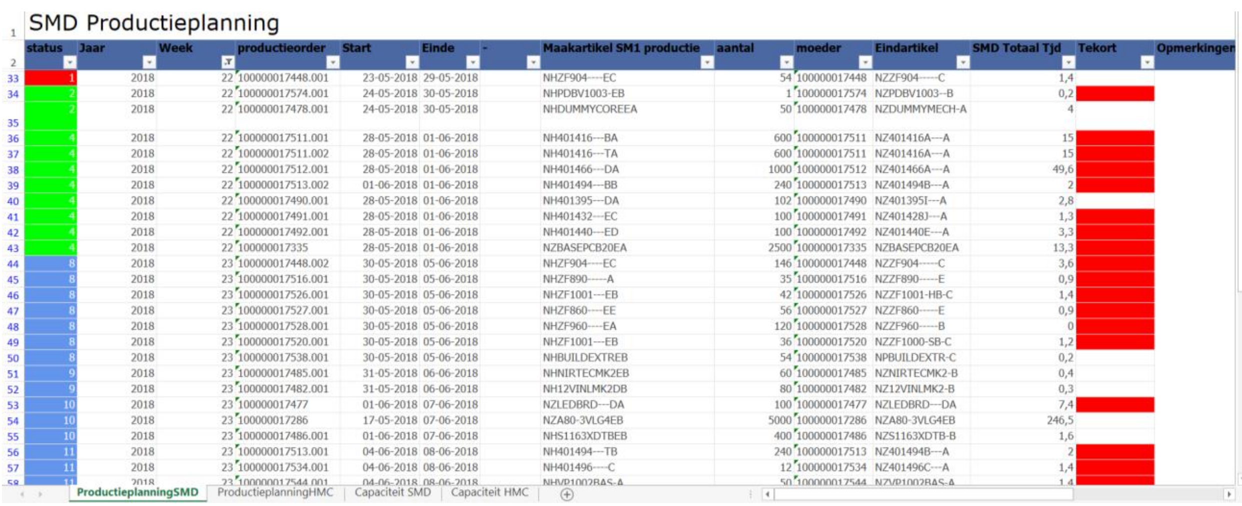
The next whiteboard that I will explain is the one at the hand assembly department. They also had a whiteboard at this department, but they did not use it in a useful way. After talking to the production leader at the department and using my own insights I created the 'new' whiteboard as shown in figure 5.8. The first three columns are the picked orders and there is a distinction between normal orders (1st column), orders 'on call' (2nd column) and orders who are 'on call' and for which the customer already made one call at least. The 4th column is the scheduling column which should be placed in front of the first three columns. This column will be used in the same way as the scheduling column at the SMD/AOI department, with the conwip principle to decrease the amount of work in progress. Then we have the three columns which express the orders on which the employees are working. First, the orders without a shortage. Second, the orders with a shortage and last but not least the orders which have partly deliveries and are not delivered in once. The next column contains orders who are at the test department, but have to come back for some final adjustments. Then the column where the employees are actually working on the final adjustments. The second-last column expresses the box-built products and the last column the final control and shipping to the customer. Again work is **pulled** from the scheduled column to the workplace to decrease the cycle time and increase the delivery reliability, because the amount of work in progress will be decreased a lot.

Figure 5.8: Scheduling board for HA

The last whiteboard is completely new and is located at the test department. Here I am not sure it is necessary to use the scheduling column, this should be based on 'trial and error'. So, I recommend to use the column in the beginning and see whether it is useful or not. The steps are testing (2nd column), oven (3rd column), 2nd test for products which come out of the oven (4th column), repair if necessary (5th column) and last column, finished products.

Figure 5.9: New whiteboard at test department

The input for the whiteboards will be generated through the ERP-system and be shown in a few Excel sheets. We made a distinction between the schedule of SMD and HA which have the same setup, in the example we will only use the SMD schedule. First of all, the schedule is generated through Exact which is shown in figure 5.10. All the production orders from the SMD department are shown in the sheet and planned to start on a certain day. This day depends on the requirements of the customer and does not yet take into account the capacity of the production lines. To create an overview within this schedule we work with different colors, to mention the status of an order, the meanings of the colors are shown in table 5.2. The second-last column shows shortages on the orders, if the cell is red the order cannot be started yet, because not all of the needed components are in the warehouse.



SMD Productieplanning

	status	Jaar	Week	productieorder	Start	Einde	-	Maakartikel SM1 productie	aantal	moeder	Eindartikel	SMD Totaal Tjd	Tekort	Opmerkingen
33	1	2018	22	100000017448.001	23-05-2018	29-05-2018		NHZF904----EC	54	100000017448	NZZF904-----C	1,4		
34	2	2018	22	100000017574.001	24-05-2018	30-05-2018		NHPDBV1003-EB	1	100000017574	NZPDBV1003--B	0,2		
35	2	2018	22	100000017478.001	24-05-2018	30-05-2018		NHDUMMYCOREEA	50	100000017478	NZDUMMYMECH-A	4		
36	4	2018	22	100000017511.001	28-05-2018	01-06-2018		NH401416---BA	600	100000017511	NZ401416A---A	15		
37	4	2018	22	100000017511.002	28-05-2018	01-06-2018		NH401416---TA	600	100000017511	NZ401416A---A	15		
38	4	2018	22	100000017512.001	28-05-2018	01-06-2018		NH401466---DA	1000	100000017512	NZ401466A---A	49,6		
39	4	2018	22	100000017513.002	01-06-2018	01-06-2018		NH401494---BB	240	100000017513	NZ401494B---A	2		
40	4	2018	22	100000017490.001	28-05-2018	01-06-2018		NH401395---DA	102	100000017490	NZ401395I---A	2,8		
41	4	2018	22	100000017491.001	28-05-2018	01-06-2018		NH401432---EC	100	100000017491	NZ401428J---A	1,3		
42	4	2018	22	100000017492.001	28-05-2018	01-06-2018		NH401440---ED	100	100000017492	NZ401440E---A	3,3		
43	4	2018	22	100000017335	28-05-2018	01-06-2018		NZBASEPCB20EA	2500	100000017335	NZBASEPCB20EA	13,3		
44	8	2018	23	100000017448.002	30-05-2018	05-06-2018		NHZF904----EC	146	100000017448	NZZF904-----C	3,6		
45	8	2018	23	100000017516.001	30-05-2018	05-06-2018		NHZF890-----A	35	100000017516	NZZF890-----E	0,9		
46	8	2018	23	100000017526.001	30-05-2018	05-06-2018		NHZF1001---EB	42	100000017526	NZZF1001-HB-C	1,4		
47	8	2018	23	100000017527.001	30-05-2018	05-06-2018		NHZF860----EE	56	100000017527	NZZF860-----E	0,9		
48	8	2018	23	100000017528.001	30-05-2018	05-06-2018		NHZF960----EA	120	100000017528	NZZF960-----B	0		
49	8	2018	23	100000017520.001	30-05-2018	05-06-2018		NHZF1001---EB	36	100000017520	NZZF1000-SB-C	1,2		
50	8	2018	23	100000017538.001	30-05-2018	05-06-2018		NHBUILDEXTREB	54	100000017538	NPBUILDEXTR-C	0,2		
51	9	2018	23	100000017485.001	31-05-2018	06-06-2018		NHNIRTECMK2EB	60	100000017485	NZNIRTECMK2-B	0,4		
52	9	2018	23	100000017482.001	31-05-2018	06-06-2018		NH12VINLMK2DB	80	100000017482	NZ12VINLMK2-B	0,3		
53	10	2018	23	100000017477	01-06-2018	07-06-2018		NZLEDBRD---DA	100	100000017477	NZLEDBRD---DA	7,4		
54	10	2018	23	100000017286	17-05-2018	07-06-2018		NZA80-3VLG4EB	5000	100000017286	NZA80-3VLG4EB	246,5		
55	10	2018	23	100000017486.001	01-06-2018	07-06-2018		NHS1163XDTBEB	400	100000017486	NZS1163XDTB-B	1,6		
56	11	2018	23	100000017513.001	04-06-2018	08-06-2018		NH401494---TB	240	100000017513	NZ401494B---A	2		
57	11	2018	23	100000017534.001	04-06-2018	08-06-2018		NH401496----C	12	100000017534	NZ401496C---A	1,4		
58	11	2018	23	100000017544.001	04-06-2018	08-06-2018		NHVP1002BAS-A	50	100000017544	NZVP1002BAS-A	1,4		

ProductieplanningSMD | ProductieplanningHMC | Capaciteit SMD | Capaciteit HMC

Figure 5.10: SMD production schedule

BLACK	This means that an order is in the backlog
RED	This means that an order needs to be delivered tomorrow
GREEN	This means that an order needs to be delivered within the same week
BLUE	This means that an order needs to be delivered after at least one week

Table 5.2: Legenda colours first column figure 5.10

One big limitation so far is that 200 hours can be scheduled in a certain week although there is not enough production capacity. As a result, we will create a backlog and a lot of orders will not be delivered on time. We made a template/dashboard to create insights about the production capacity of a week which is shown in figure 5.11.

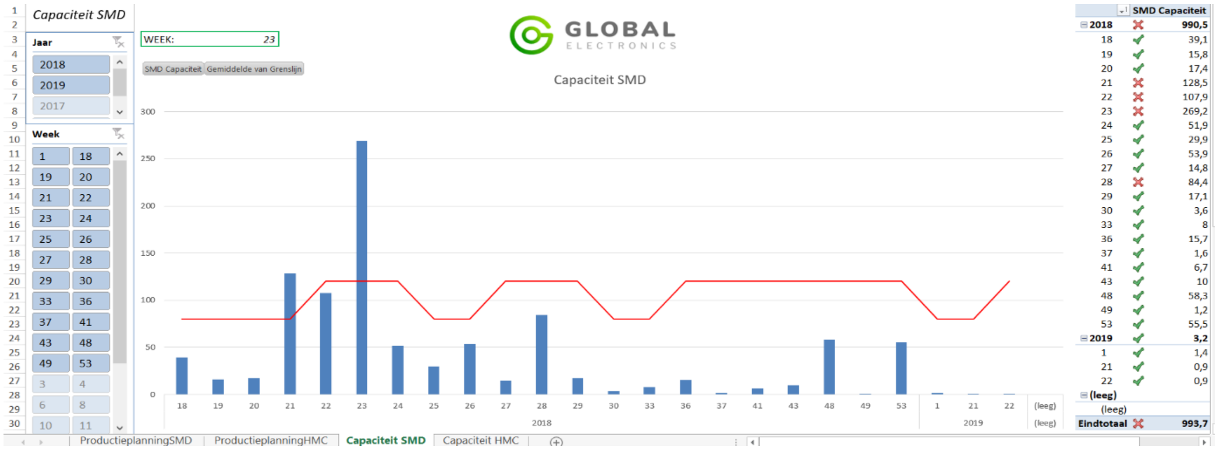


Figure 5.11: Dashboard showing production capacity

The red line shows the production capacity of a week and every column shows the number of production hours needed for that week. I added filters on the left side, so you can hide all the weeknumbers that you do not want to see, you can also hide years if you want to. This template is copied in week 22, which means that the backlog in weeks 18, 19, 20 and 21 should still be done in the future. Besides, the amount of work planned in week 23 is a lot more than the actual capacity, which will result in a lot of problems. As you can see the 'SMD Productieplanning' (figure 5.10) does not work yet as desired, but it is a good start, realizing that nothing of this existed at the beginning of my research. In the desired situation the backlog is automatically scheduled in the future. Furthermore, it should be impossible to schedule orders in a week which is already full of capacity. These issues are not within the scope of my project and will be worked on by the production manager. **After these issues are fixed we can use these sheets as input for the whiteboards in the different departments. The explanation of how to use the sheets as input for the whiteboards will be explained in chapter 6.**

- **SMD and HA are two completely different production steps, which should be covered in the planning system in a suitable way.**

When a production order is finished at the SMD/AOI department the PCBs will be transported to a (new) created location close to the HA department. This location is shown in figure 5.12 and highlighted by the red line. If a SMD operator places the PCBs here it runs to the whiteboard of the HA department and marks the production order card of HA which is related to the production order card of SMD. In this way the employees at the HA department knows exactly which orders they can start and which orders they cannot start. Another advantage with this system is that they do not need to search for the PCBs, because they are always placed in the same place. This was not the case before I introduced this idea.

Figure 5.12: New product rack

- **Policies and limits should be created.**

Capacity limits can be placed into a table in Excel and with a push on the button the red line will appear in the template/dashboard. Those limits should be determined by the production manager and the scheduler.

5.4 KPI's to use in combination with the scheduling system

It is important to use KPI's in combination with the new scheduling system, because otherwise we will not know whether the new system increased the overall performance of the company or not. As mentioned earlier we wanted to increase the delivery reliability, so this will be the first KPI I want to introduce to the company.

The delivery reliability will be described as follows: *"The extent to which the right numbers are delivered at the right time"*. A new function in Exact is added to measure the delivery reliability. The scheduled delivery date is placed manually into the system and will freeze after the customer confirms the date. After a while when the order is delivered to the customer a delivery date is created in Exact. With this information a report can be created and the delivery reliability can be measured in every moment of time. Because, this is new we do not have any historical data, so we cannot yet track the delivery reliability in this way. After a few weeks this KPI will be added to the production board, so that the employees can see their overall performance during time. We already did a zero measurement at the start of my research project which stated that **the current delivery reliability is 57%.**

6. Conclusions and Recommendations

In this chapter we start with a short conclusion about the introduction of the pull system. We continue with recommendations about the delivery reliability and how to use the excel sheets in combination with the (new) whiteboards. In addition, we recommend why GE should introduce a 'scheduler' and use flexible people. Furthermore, improvement projects are mentioned which can be executed in the future.

6.1 Outcomes systematic literature review (RQ1)

By answering my first research question: "What are the critical success factors for using LEAN to analyze the problems of processes in a manufacturing company?" I got the following critical success factors:

1. It is important to build up a team with experts and the skills needed to be successful in using LEAN.
2. Make use of Value Stream Mapping.
3. It is important to train the right people and first let them learn by doing.
4. Create an organizational culture in which monitoring and controlling is taken into account to use LEAN for analysis in your organization.

I can (definitely) conclude that all of those factors came back during my research which I will explain shortly for each factor.

First of all, once in a few weeks a LEAN consultant helped our LEAN management team to use LEAN within Global Electronics. So, we made use of an expert which was really helpful and pushed us in the right direction. He also gave me a lot of useful advice and information which helped me to create a new scheduling system, based on LEAN principles.

Secondly, I used Value Stream Mapping at the start of my research project which gave a lot of useful insights about the problems of the company. Furthermore, it became easier to come up with solutions, because of the useful insights.

Thirdly, after we created the new scheduling system we first let the people learn by doing. We created a short explanation and after that we wanted to see what happened. A lot of people started working with the new system and after a while we trained them how to use the system exactly. This was a good way to motivate the people and they are still working with the new system.

Last but not least, this step is taken into account as well by creating the KPI 'delivery reliability'. This will be used to monitor the performance of the organization. I recommended to create one or two more KPI's which will be done in the future, to make it easier to control the performance of the organization.

6.2 Introduction first pull system (eye opener)

The first pull system that I introduced was mostly based on theory and less on practice. After presenting my ideas to the management team and production leader, it seemed to be that the system does not work (yet) in the organization although it is a perfect system in theory. Therefore, I had to make a lot of alterations and this time I worked together with some of the employees to keep in mind the issues in practice, that I took less in mind with the creation of the first system. This resulted in something that works and is already implemented at the shop floor. I can conclude that it was really good to come up with a system that does not work immediately and make a lot of alterations, than just **talk about possible systems** without creating anything. Besides it is important to involve the people who have to work with the system to combine your own theoretical background with the practical background of them.

Furthermore, the pull idea of the first system will be used in the current scheduling system.

6.3 KPI delivery reliability

Use the KPI delivery reliability to show the employees the actual performance of the company. We are aiming to increase the delivery reliability with the new scheduling system. To do this we make use of the Exact, the ERP-system. In this system the employees put the (first) appointed delivery date which will be frozen after the customer confirms the date. When the product will be delivered the actual delivery date will be created. By analyzing the difference between those dates we can state the delivery reliability. For example, 7 times the 'frozen date' is the same as the delivery date and the delivery date is 3 times later than the 'frozen date' we will have a delivery reliability of 7/10*100% = 70%. This calculation can be done automatically by the ERP-system. If we can prove that the change of system increases the delivery reliability the employees will see the utility of the changes made. Without using this KPI we cannot show hard proof to the employees that the changes increased the performance of the company. This can be used against the management team which should be prevented.

6.4 Combination between scheduling system (whiteboards) and ERP-system

In chapter 5 I described the new scheduling system and the limitations of the 'SMD productieplanning' (figure 5.10) generated by Exact. After this system is altered, so that the desired situation is achieved and we can start using the whiteboards as schedule some weeks/months will pass by. Therefore, I will give my advice on how to start using the whiteboards as schedule for production.

SMD Productieplanning

status	Jaar	Week	productieorder	Start	Einde	-	Maakartikel SM1 productie	aantal	moeder	Eindartikel	SMD Totaal Tjd	Tekort
1	2018	22	100000017448.001	23-05-2018	29-05-2018		NHZF904----EC	54	100000017448	NZZF904-----C	1,4	
2	2018	22	100000017574.001	24-05-2018	30-05-2018		NHPDBV1003-EB	1	100000017574	NZPDBV1003--B	0,2	
2	2018	22	100000017478.001	24-05-2018	30-05-2018		NHDUMMYCOREEA	50	100000017478	NZDUMMYMECH-A	4	
4	2018	22	100000017511.001	28-05-2018	01-06-2018		NH401416---BA	600	100000017511	NZ401416A---A	15	
4	2018	22	100000017511.002	28-05-2018	01-06-2018		NH401416---TA	600	100000017511	NZ401416A---A	15	
4	2018	22	100000017512.001	28-05-2018	01-06-2018		NH401466---DA	1000	100000017512	NZ401466A---A	49,6	
4	2018	22	100000017513.002	01-06-2018	01-06-2018		NH401494---BB	240	100000017513	NZ401494B---A	2	
4	2018	22	100000017490.001	28-05-2018	01-06-2018		NH401395---DA	102	100000017490	NZ401395I---A	2,8	
4	2018	22	100000017491.001	28-05-2018	01-06-2018		NH401432---EC	100	100000017491	NZ401428J---A	1,3	
4	2018	22	100000017492.001	28-05-2018	01-06-2018		NH401440---ED	100	100000017492	NZ401440E---A	3,3	
4	2018	22	100000017335	28-05-2018	01-06-2018		NZBASEPCB20EA	2500	100000017335	NZBASEPCB20EA	13,3	

Figure 6.1: Conwip for one week

Every week on Monday morning the person responsible for the schedule has to open the template in Excel (figure 6.1) filter on the current week and put all the production orders scheduled for that week on the SMD/AOI & HA whiteboards. This should be the only point of time on which work is placed onto the whiteboard (in the perfect situation). There is a special lane (column) to place the scheduled orders, in this lane the scheduler can make priorities of which orders should be produced first. The sequence of orders can be changed at any point of time if this is necessary, which makes the system flexible. The employees can pull a production order towards them when they are ready for it. With this system we want to create a constant level of WIP, which should get lower over time if the system improves. As a result, the delivery reliability should increase, the cycle time and working capital should decrease. Introducing this new way of scheduling and working should be introduced by trial and error. Just try out my advice and alter the way of working if necessary.

6.5 Introduce a production scheduler as soon as possible

A production scheduler is definitely missing within the company and should be introduced as soon as possible, "preferably today rather than tomorrow". I believe this is one of the most important functions within the company. The production scheduler will be the contact person between the sales department and the production leader and processes their wishes in the schedule. For example, if customer x asks for an order to be delivered a week earlier, the sales person should communicate with the production scheduler whether this is possible or not. The (new) hierarchy with a production scheduler is shown in figure 6.2. I would recommend to ask somebody who can think 'out of the box', thinks in solutions rather than problems and has good communicational skills. Besides, it is important that the person strives for continual improvement.

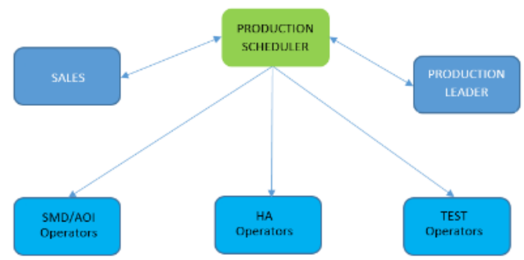


Figure 6.2: New hierarchy with production scheduler

6.6 Make use of 'butterflies/jokers'

I would recommend to introduce 1 or 2 people who do not have a standard job, but can help in most parts of the organization. In this way bottlenecks can be tackled easier and as a result a better **flow** will be created. In addition, in case of an emergency order which should be delivered very fast you can use the butterfly/joker in every step of the production process to finish the order as soon as possible. When they are not busy I would recommend to let them help at the end of the supply chain to increase the finishing speed of production orders. The focus should be on **finishing** rather than starting a production order.

6.7 Recommendations for improvement in the future

During my research project my focus was on the improvement of the scheduling system. But, I faced a lot of other points of improvements which should be covered in future projects which are as follows:

6. Inventory management; A challenging project which should face the problem of obsolete stock.
7. SMD-uptime; The machines at the SMD department are down half of the time, so use improvements can be made.
8. HA process; Hand Assembly takes a lot of time and is one of the bottlenecks within the organization. Starting a project about optimization of the supply chain at HA can result in a lot of time saving.
9. Starting earlier with the purchase process; The delivery of components increases the cycle time of an order a lot, again a lot of time saving can be achieved by changing the way of working.
10. Make use of customer order forecasting if possible;

References

Achanga, P., Nelder, G., Roy, R., & Shebab, E. (2006). Critical succes factors for lean implementation in SMEs. *Journal of Manufacturing Technology Management*.

Brandon-Jones, A., Johnston, R., & Slack, N. (2013). *Operations Management.* Harlow: Pearson Education Limited.

Dumrak, J., Soltan, H., & Mostafa, S. (2013). A framework for lean manufacturing implementation. *Production and manufacturing research*.

Greaves, K., & Laing, S. (2018). *Kanban in de praktijk.* Hilversum: NUBIZ.

Heerkens, H., & Winden, A. v. (2012). *Geen probleem.* Gorcum: Van Winden Communicatie.

Jones, D., & Womack, J. (1996). *Lean thinking: Banish waste and create wealth in your corporation.* London: Simon & Schuster.

Liker, J. K. (2004). *The Toyota Way.* New York: McGraw-Hill.

Plex. (2017). Push vs. Pull Manufacturing: Is a Kanban Pull System Right for Your Company? *Industry Week*. *Picked up from: http://www.industryweek.com/cloud-computing/push-vs-pull-manufacturing-kanban-pull-system-right-your-company*

Theisens, H. (2016). *Lean Six Sigma Black Belt Mindset, Skill set and Tool set.* Amstelveen: Lean Six Sigma Academy.

Theisens, H. (2017). *Lean practitioner & lean expert.* Amstelveen: Lean Six Sigma Academy.

Theisens, H. (2016). *LEAN SIX SIGMA, Green Belt; Mindset, Skill set and Tool set.* Amstelveen: Lean Six Sigma Academy.

Appendix 1

To determine the core problem in the organization in a systematic way I used “De Algemene Bedrijfskundige Probleemaanpak” (Heerkens & Winden, 2012). This approach contains seven different phases, namely:

- Phase 1: The problem identification
- Phase 2: The formulation of the problem approach
- Phase 3: The problem analysis
- Phase 4: The formulation of alternative solutions
- Phase 5: The choice
- Phase 6: The implementation
- Phase 7: The evaluation

Probably only phases 1-4/5 will be executed during my graduation project. The other phases will be interesting for the management team, because they can use them to implement my ideas.

Appendix 2

In this appendix we can found back the inclusion and exclusion criteria. How we filtered on articles and the context matrix for the systematic literature review to answer research question 1.

#	Criteria	Reason for inclusion
1	Articles should be in Dutch or English	If they are not in Dutch or English I cannot read the articles
2	Full text should be available	If the full text is not available the article is not useful
3	Subject should be about Engineering and/or Business Management and Accounting	I am operating in a surrounding where Engineering and Business Management and Accounting is present
4	Focus on improving	LEAN can also be about controlling, which is not the subject I want to review on

Table A1.1: Inclusion criteria SLR

#	Criteria	Reason for exclusion
1	Articles published before 1988	1988 was the first year when they started to write about LEAN
2	Articles should be free	I do not want to spend money on expensive articles
3	Articles about Six Sigma	I do not want to take into account Six Sigma which has significant differences with LEAN
4	Service companies	My focus is on manufacturing companies

Table A2.2: Exclusion criteria SLR

Search string	Search date	Scope	Number of results
LEAN AND "success factors" AND (compan* OR organization*)	25th of march 2018	Article title, abstract, keywords	214
		After including inclusion and exclusion	59
		After reading the title	43
		After reading the abstract	19
		Based on availability	8
		After reading	4
		After Backward searching	6

Table A2.2: Filtering on articles

Document type	Authors (years)	Factors	Methodology	Key findings
Conference paper	Bin Wan Ibrahim, W.M.M.; Rahman, M.A.; Bin Abu Bakar, M.R.	1,2,3	Multiple case study on Malaysian SMEs in the pharmaceutical industry	The critical success factors for implementing Lean at Malaysian SMEs regarding the pharmaceutical industry are as follows: 1. Top management support & understanding 2. Attitude of the employees 3. Knowledge of implementation 4. Government support
Conference paper	Zargun, S.; Al-Ashaab, A.	1,3,4	Extensive literature review on the adoption of LEAN Manufacturing in developed countries	The recommended critical success factors for developing countries are as follows clustered in four categories: 1. Strategy & Objectives 2. Leadership & Management 3. Human Resources 4. External Factors
Conference paper	Gunasekharan, S.; Elangovan, D.; Parthiban, P.	1,3,4	Extensive literature review and expert consultation was carried out to identify the factors that affect the lean implementation in Indian manufacturing industries	The following factors are needed to make the implementation of LEAN in Indian manufacturing companies easier: 1. Management and Leadership 2. Resistance to change 3. Employee trust 4. Skills and expertise 5. Financial capabilities 6. Communication of the transformation process 7. Performance measures 8. Education and training 9. Plan and strategy 10. Thinking development 11. Customer focus
Conference paper	Xu, L.X.X.; Wang, F.Y.; Lim, R.; Toh, M.H.; Valliappan, R	1,2,4	Literature review about Lean implementation in SMEs from a Singapore context	The most common recognized success factors are: 1. Top management commitment 2. A structured lean program that is aligned with the company's long term goal and vision 3. A visual communication mechanism to publish the lean wins

				4. KPIs are well-defined, monitored and aligned closely with lean projects
Journal	Roslin, E. N.; Ahmed, S.; Dawal, S. Z. Md.; Tamri, N.	1	A case study in a Malaysian automotive parts manufacturing	The critical success factor in this company for implementing LEAN is: - The commitment afforded by the top management.
Conference paper	Bakas, O.; Govaert, T.; Van Landeghem, H.;	1,4	A literature review and a multiple case study from Norwegian and Belgium SMEs	The critical success factors that are suggested in this paper are: 1. Ensure strong leadership and management involvement 2. Allow for thorough employee involvement and sufficient participation 3. Allocate sufficient time for preparing the organization 4. Make sure that there exist sufficient motivation for completing initiatives 5. Build competence in the internal organization 6. Make sure a performance evaluation system is established in parallel

Table A2.3: Context matrix

Appendix 3

By analyzing the current supply chain I asked a lot of people about their insights, I stated the most important insights below:

Production manager
1.1: ‘Estimated changeover time is around 1 hour, but this contains a small difference between orders’
1.2: ‘The theoretical times are already times 2 the ‘real’ theoretical times, because practice always shows a lot of differences with the theory’

SMD line operator
2.1: ‘2 days waiting time between SMD and AOI is a short period in the worst case scenario it runs up to 2 weeks’
2.2: ‘A lot of waiting time of the machine is caused by shortages from the warehouse.’

SMD line preparation
3.1 ‘If an order is picked in the warehouse and brought to the SMD line preparation, they start preparing the trolleys for the SMD line as fast as possible in which the waiting time has a maximum of 1-2 hours.’

Hand Assembly manager
4.1: ‘The cycle time at the solder production step is determined by the number of solder points on a PCB, about 2-4 seconds per solder point.’
4.2: ‘The time between AOI and HA is created by the delivery date of the different orders, so when the order needs to be delivered the same week we start with the HA (almost) immediately, otherwise we wait with the order.’
4.3: ‘We stop with a production order if there is a higher priority for another order.’
4.4: ‘The different production steps within HA are always done after each other with as less waiting time between the steps as possible.’

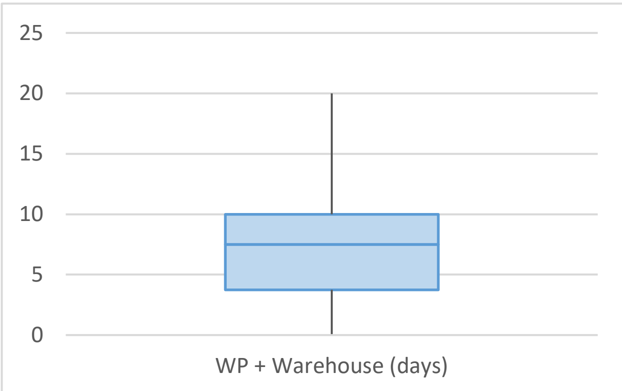
AOI programmer
5.1: ‘Programming at the AOI machine can vary from 15 minutes till half a day’

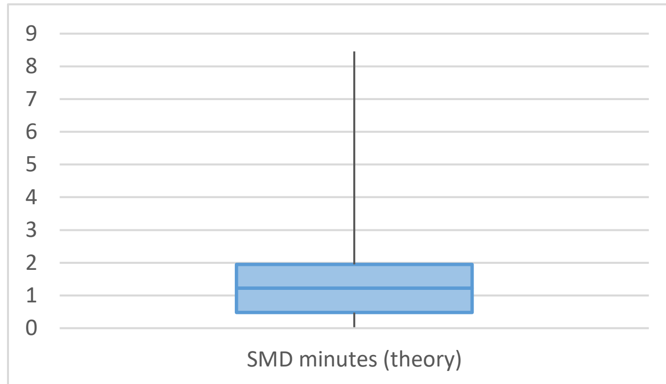
Test operator
6.1: ‘The cycle time of testing varies per order, but most of the time it is a few minutes per PCB’
6.2: ‘Testing is done based on delivery date, so if an order needs to be delivered that day they start testing, but if that is not the case the waiting time between HA and Testing can vary between 1 day and a week.’

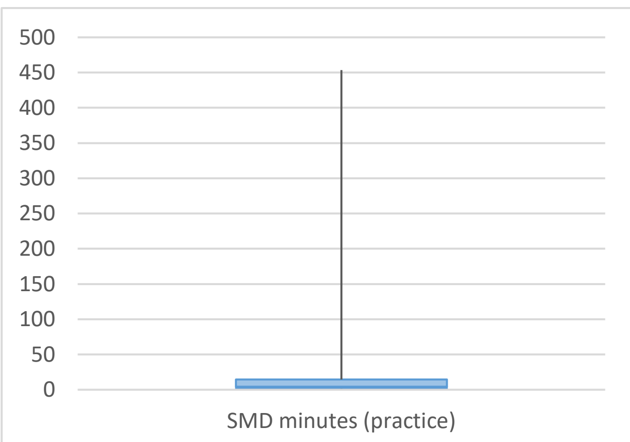
Warehouse manager
7.1: ‘On average it takes 5 days between printing an order in the warehouse -> preparing the order progress map -> picking the components in the warehouse.’
7.2: ‘If final control is finished it takes a maximum of 1 day to pack and send the end products to the customer.’
7.3: ‘Packaging and sending takes a minimum of half an hour and can increase till 2 hours, sometimes it is even longer depending on the complexity of the PCBs.’

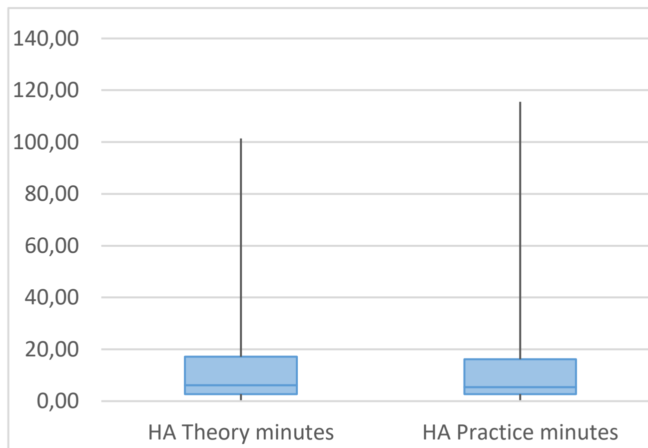
Appendix 4

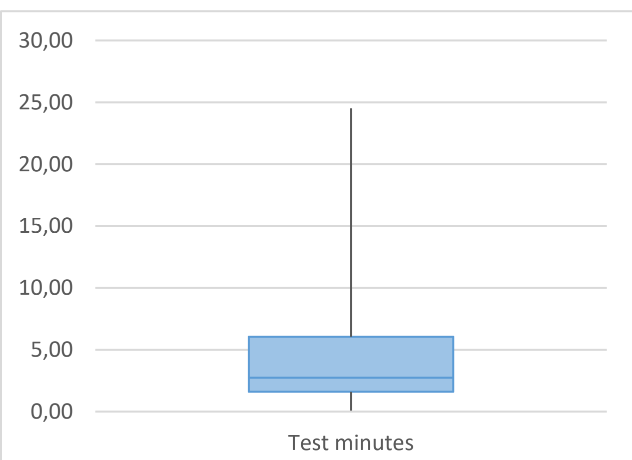
I used boxplots to make a more specific analysis of the cycle times and waiting times within the supply chain.

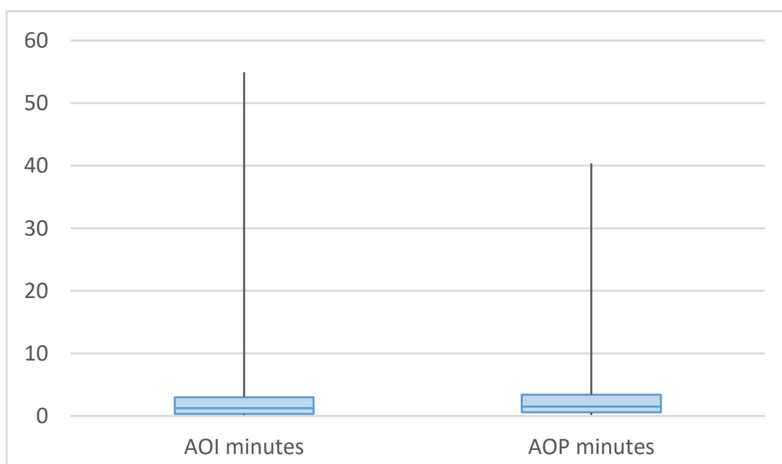


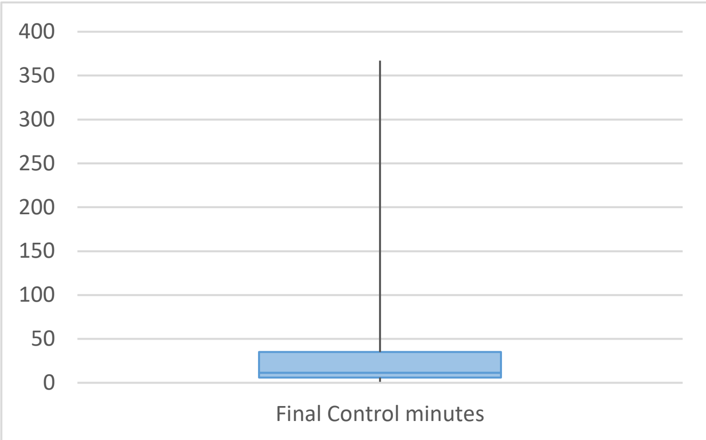


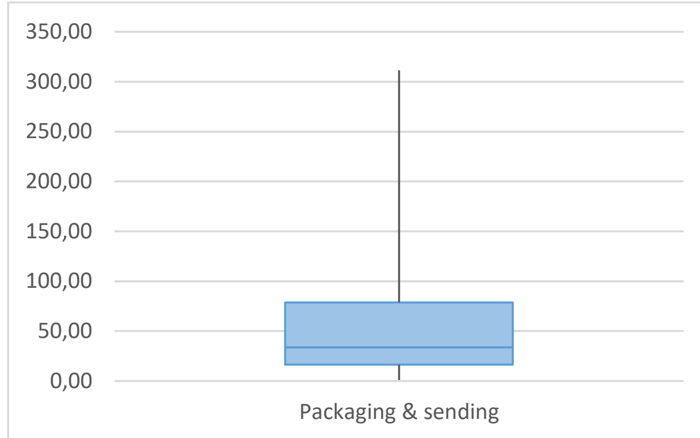









400
350
300
250
200
150
100
50
0
Final Control minutes


350,00
300,00
250,00
200,00
150,00
100,00
50,00
0,00
Packaging & sending

Appendix 5

For the creation of the capacity line in the excel capacity template/dashboard I used an excel macro as shown in this appendix.

Capaciteit Berekenen

Week	Capaciteit
1	80
2	80
3	80
4	80
5	80
6	80
7	80
8	80
9	80
10	80
11	80
12	80
13	80
14	80
15	80
16	80
17	80
18	80
19	80
20	80
21	80
22	120
23	120
24	120
25	80
26	80
27	120
28	120
29	120
30	80
31	80
32	80
33	80
34	80
35	120
36	120
37	120
38	120
39	120
40	120
41	120
42	120
43	120
44	120
45	120
46	120
47	120
48	120
49	120
50	120
51	120
52	120
53	120

```
Option Explicit

Dim i, j As Integer
Sub Grenswaarde()
For j = 3 To 500
    For i = 3 To 55
        If Cells(j, 3) = Cells(i, 20) Then
            Cells(j, 15) = Cells(i, 21)
        End If
    Next i
Next j
End Sub


Sub GrenswaardeSMD()
For j = 3 To 500
    For i = 3 To 55
        If Cells(j, 3) = Cells(i, 20) Then
            Cells(j, 15) = Cells(i, 21)
        End If
    Next i
Next j
End Sub
```