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Module 11: Thesis preparation

Production process improvement of dredger hardware

powerspex

Colophon

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This thesis has been written as a final graduation requirement for my studies in Industrial Engineering & Management at the University of Twente. Due to confidentiality the numbers in this report are multiplied with a random factor and the customer of Powerspex is made anonymous.

Summary

Problem

Currently, Powerspex Instrumentation B.V. is providing company X with the hard- and the software for the Cutter Suction Dredgers that company X is making. Company X wants to become a market leader in the Cutter Suction Dredger market. To become a market leader they will need to keep innovating and so do their suppliers. The goal of innovating is mainly to keep the prices of the dredgers low and the value for the customers of company X high. Part of this value is to keep their lead times as low as possible, this means that company X values suppliers with low prices, by keeping the number of working hours as low as possible and short lead times. Powerspex can have (a) more (immediate) influence on reducing the number of working hours than on reducing the lead times of the dredgers. In addition, the number of hours spent in the production process, which is about 42,346 hours on average on a Cutter Suction Dredger 500 is quite much and should be able to be reduced to about 32,202 working hours. Both these reasons brought me to the next research question: '*How can Powerspex reduce the number of working hours for the production of a dredger by improving the (production) process from a lean perspective?*'

Methodology

By observing the process and holding interviews with stakeholders I was able to draft process maps and estimate the times that the activities in the process take. Using the time estimates of the employees for the activity times within the process of producing the dredger hardware for a CSD500 adds up to a total of 17,550 hours. The 17,550 hours is not very close to the actual number of hours spent within the production process, which is 42,346 hours, because of multiple reasons like the travelling hours that are not taken into account or the smaller activities that the employees might not have considered. The estimates can however still help us to approximate the number of hours saved by implementing a solution. With the help of a literature research for non-value adding activities and an interview with the purchasing manager of company X I identified the non-value adding activities visualized below in Table 1.1:1.

#	Non-value adding activity
1	Walking up and down the dredger every time for needed tools or materials
2	Walking back and forth in the workplace for required materials and tools
3	Walking back and forth within the dredger when pulling, connecting and bundling the cables
4	Bundling the cables perfectly neat within the dredger and in the workplace in Hengelo
5	Searching the materials on the pallet of the dredger and searching for the lost materials
6	Measuring and drawing for drilling holes or die-punching
7	Fastening the tie-wraps to the cable ladders
8	Peeping through (testing if all cables are well connected with a special electronic device (=multimeter)) the cabinets, plate and the DESKs
9	Reconnecting the cables or resolving other faults after testing with either peeping through or Proneta
10	Testing the cabinets and operating cabin with Proneta
11	Adjusting changes in electrical schemes
12	Rebuilding the LED-lights
13	Aftercare of the cabinets and operating cabin

Table 1.1:1; The non-value adding activities found within the production process.

By making a problem cluster the root causes of the non-value adding activities have been found and with these root causes I have found the solutions to either eliminate the non-value adding activities from the process or to reduce the time spent on the non-value adding activities. The next root causes

have been found (between brackets is the number of the non-value adding activity that they are causing, which refers to the numbers above in Table 1.1:1):

- The employees do often not know which materials they need and how many exactly before they start the activity (#1).
- The employees cannot (easily) see which materials are booked in (#5).
- Booking in the materials via AGP is quite unpractical (#5).
- There is not a device available in the workplace that is both connected to the server of Powerspex and can make pictures (#13).
- The maps (with the electrical schemes) are scanned by hand (#13).
- All materials of the dredger are put on the same pallet (#5).
- There is not a fixed layout of the electrical cabinets (#6).
- Not all materials are available to either automate the activity of drawing and measuring or to make the activity of drawing and measuring less time consuming (#6).
- The current LED-lights that are used are unpractical (#12).
- The cables have to be placed with tie-wraps on a vertical placed cable ladder (#4 and #7).
- The cables are bundled in full-sight (#4 and #7).
- There is a lack of standardization regarding the process and the people working on the process (#8, #9, #10, and #11).
- A lot of testing the cables is done by hand, which makes it prone to human errors (#8, #9, #10, and #11).
- A lot of hardware is double tested (#8, #9, #10, and #11).

The solutions have been evaluated by means of the number of hours they can save, the investment costs involved and the other (dis)advantages. Assessing the solutions has resulted in a few solutions for Powerspex to be recommended. Below in Table 1.1:2 the non-value adding activities with their solutions, required investment costs and number of saved hours are listed.

Non-value adding activity	**Solution**	**Number of saved hours**	**Investment costs**
Testing and rework	To not test the PLC-related parts, but only the power supplies (short-term solution)	470 hours	-
	To develop a software program that can perform the peeping through and Proneta test at once (long-term solution)	1,073 hours	€135,248
Search work	Divide the pallet in 4 compartments	403 hours	Negligible
	Using an iPad to see if the materials are already booked in	81 hours	€0, if iPad is bought for the other solution
Aftercare	Buy an iPad that is both connected to the server of Powerspex and can make pictures	81 hours	€31,826
Walking up and down the dredger	Use material boxes (that are filled in Hengelo), so the employees always have all needed materials with them	403 hours	€1,932
Bundling the cables	To be determined, more on this is explained within the implementation plan	Maximum 1,208 hours	Difficult to estimate for all three the solutions

Measuring and drawing	Outsourcing the activities of drilling and die-punching	1,109 hours	Hours of the hardware engineer to make the Auto CAD drawings + the extra outsourcing costs
Rebuilding the LED-lights	Buy LED-lights that are more practical to connect	215 hours	For Powerspex: €0

Table 1.1:2; The non-value adding activities listed together with the solutions, number of saved hours and the required investment costs.

For the implementation a plan is made. The implementation plan is considered especially useful for the solutions of bundling the cables and developing a software program. The implementation plans of these solutions are discussed under the recommendations below. To evaluate the implemented solutions I have made a dashboard for Powerspex. The dashboard contains 4 pages and visualizes the most relevant data for Powerspex to keep an eye on. The graphs in the dashboard contain information about the profits of each project, the total costs of each project, the height and the division of the labour costs of each project and the allocation of other costs for each project. The third page is especially useful to evaluate the implemented solutions as it represents the information on the labour costs of the projects. On the right in Figure 1.1:3, the page of the labour costs is given.

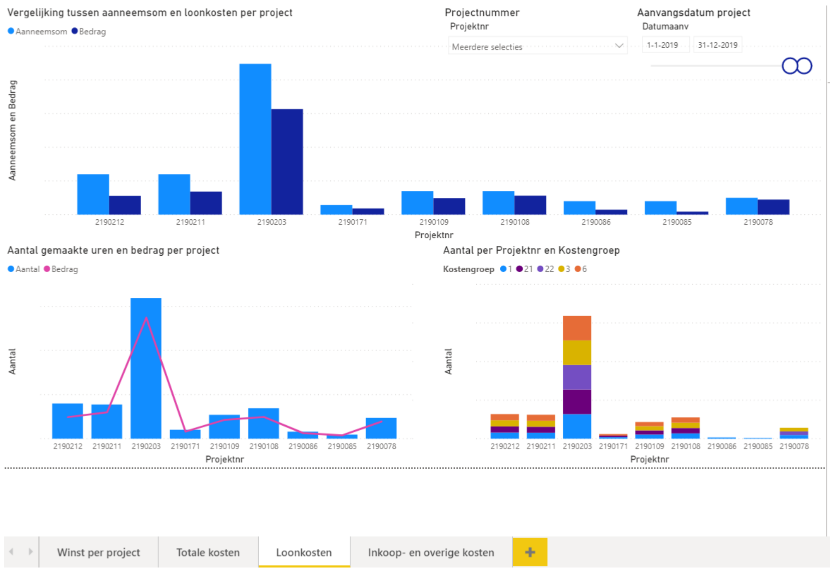

Figure 1.1:3; The page of the dashboard that visualizes information about the labour costs per project within Powerspex.

Recommendations

<u>IPad</u>

In order to reduce the number of working hours the purchase of an iPad is recommended to use for both the aftercare of the cabinets and the operating cabin and to check which materials are already booked in, in AGP.

<u>Search work</u>

I would recommend the management of Powerspex to divide the pallets into 4 compartments, so the search work for materials before assembling an electrical cabinet can be reduced as much as possible.

<u>Testing and rework</u>

To reduce the time spent on testing and rework I would recommend the management of Powerspex to leave out the activity of peeping through the PLC-related parts on the short-term. However, on the long-term I would recommend hiring an intern from the discipline of Technical Computer Science or Electrical Engineering to develop a software program for testing the cabinets and operating cabin.

<u>Material boxes</u>

To reduce time that employees of Powerspex are walking up and down the dredger, I would recommend the management of Powerspex to use material boxes. The boxes can be best filled in the workplace in Hengelo with a list of the required materials for each process. The boxes can then be picked up by the supervisor onsite.

Bundling the cables

In order to reduce the time spent on pulling and bundling the cables (as neatly as possible) Powerspex will have to do a trial first with the solutions of using cable harnesses, using pipes of about 3 to 4 meters long and using cable gutters within the dredger. Next Powerspex will have to do some research for themselves, involving Bureau Veritas, company X and other external parties to implement a final solution to reduce the time spent on this non-value adding activity.

Measuring and drawing

To eliminate the activities of measuring and drawing the plates and doors, outsourcing is a good method. However, Powerspex will have to keep an eye on the outsourcing costs and evaluate the possibility to improve the number of hours spent within the process when they perform the activities themselves.

LED-lights

To eliminate the time spent on rebuilding the LED-lights at the assembly onsite I would recommend the management to look for other heat-resistant LED-lights available in the market that are more practical to assemble. Then Powerspex will have to propose the product to company X.

Evaluating the number of working hours

During the research it was noticed in the beginning that some employees do not exactly know where the hours are spent in the process. For the project manager it would therefore be useful to have the employees registering their hours more specific for activities and processes so he and company X both can have more insights in where the hours in the process are spent. In addition, I would recommend the management of Powerspex to more precisely measure the time that the activities take. When the activity times are known better, more insights can be obtained and the management is better able to continuously improve (the performance of) the operations. Finally, I would recommend the management of Powerspex to evaluate the implemented solutions with the dashboard that I have made and keep a close eye on the development of the profits and the labour costs.

Preface

Dear reader,

In front of you is the thesis 'Production process improving of dredger hardware'. This thesis has been written to finalize my studies Industrial Engineering & Management (BSc) at the University of Twente. The research for this thesis has been conducted from February 2020 until August 2020 in commission of Powerspex Instrumentation B.V.

By performing interviews and observing the process in both Hengelo and City A where company X, the customer of Powerspex, is located I have conducted this research. This required the cooperation of several employees working both within Powerspex and company X. Through this way I would like to thank all of them who have helped me in any kind of way to conduct this research. Their openness and willingness to think along have helped me to get thoughtful insights into their processes and to make an adequate recommendation to the management of Powerspex. In particular I would like to thank Gerko Dubbink, my internal supervisor within Powerspex. He helped me on my way by introducing me to the team and the process, could always give me useful insights during the research and always wanted to make time for me, despite his busy schedule.

In addition, I would like to thank Leo van der Wegen, my supervisor from the University of Twente. He was always available to give me good constructive feedback whenever I needed it and helped me to improve the quality of both my research and this thesis. Also I would like to thank Wouter van Heeswijk to read along with my research and to review my thesis.

Finally, I would like to thank my friends and family for showing their interests in my research and supporting me in any form possible, especially for keeping me motivated during the strange Covid-19 situation.

I hope you will enjoy reading my thesis!

Bart Snoeijink
Hengelo, August 2020

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Definitions and abbreviations

AGP	The ERP-system (=Enterprise Resource Planning system) that Powerspex uses.
BPMN (2.0)	Business Process Model and Notation, is a widely applied and accessible method to visualize business processes. 2.0 Refers to the version of BPMN that has been released, this new version contains amongst others more detailed symbols to be used in the process models.
Commissioning	“Inbedrijfstelling” in Dutch, which is the part where the ship is being tested in its totality to filter out possible mistakes.
CSD	The CSD part stands for Cutter Suction Dredger. Then whenever there is a number behind this CSD it indicates the pipe diameter of the dredger in millimeters. So CSD500, refers to a dredger of company X with a pipe diameter of 500 mm.
company X 2.0	Currently company X is developing a revised version of the current Cutter Suction Dredger, which is called the company X 2.0 project within Powerspex.
company X	This is the customer of Powerspex, which belongs to the company Y.
company Y	This is the name of the company X group, which is the umbrella company for a lot of smaller companies, to which company X also belongs.
DESK	Is almost the same as a SK (“SchakelKast”), however the difference is that a DESK is not an iron box, but rather a dashboard plate in which components are placed. These components are connected to an electrical system again. This device enables the user to easily interact with an electrical system and to control it.
DIN-rails	An iron rail, mounted in the electrical cabinet, on which the components of the electrical cabinet can be easily placed.
Dredger	A vessel which is equipped for the removal of sediment or sand in a body of water. Often when there is referred to a dredger within this thesis there is referred to a Cutter Suction Dredger.
E&I	Electrical and Instrumentation
MPSM	Managerial Problem Solving Method. This is a method to systematically solve problems, by using 7 Phases.
Multimeter	A device that can be used to measure different electrical magnitudes, like amperage and voltage.
Pontoon	A floating platform on which the dredger will be built. The pontoon will keep the dredger afloat.
Proneta	The software that Powerspex uses to see if the PLC (=Programmable Logic Controller) is rightly connected. Whenever someone is testing with Proneta, it means that he is testing if the software is doing what it should do.
SK	Is an abbreviation for “SchakelKast” in Dutch, which is a synonym for an electrical cabinet in this report. An electrical cabinet is an iron box, in which components are placed that enable an electrical system to be controlled. The number behind SK indicates the type of electrical cabinet.
Swivels	Small rotatable clamp that keeps the cables in place.

1 Problem identification

In Section 1.1 I will first provide some relevant information about Powerspex and in Section 1.2 I will discuss the problems that Powerspex has identified. Then I will dive deeper into the production process of both the dredger and of the hardware for this dredger that Powerspex is providing in Section 1.3. Both the problems will be more thoroughly analysed and one of both the identified problems will be chosen for this research to focus on in Section 1.4. With the general problem identified, I will have to work towards a solution. To work towards the solution a methodology is discussed in Section 1.5. The main research question is drafted in Section 1.6, before the other 7 research questions are drafted in Section 1.7 together with the explanation of how the answers will be obtained. Finally, the intended deliverables are discussed in Section 1.8, before Chapter 1 will be concluded in Section 1.9.

1.1 About Powerspex

Powerspex Instrumentation B.V. is located in Hengelo and is specialised in automation solutions for a variety of industries. Powerspex is active in the market for three different specialisations, namely Powerspex is offering hardware solutions, software solutions and maintenance services. Customers of Powerspex are some of the biggest employers both within The Netherlands and outside of The Netherlands. Company X is one of the customers of Powerspex and this customer is producing dredging solutions in different forms. One of these dredging solutions is their Cutter Suction Dredger (CSD), which is depicted in Figure 1.1:1. The CSDs are produced in five different sizes, namely the next CSDs are available at company X: CSD250, CSD350, CSD450, CSD500 and CSD650. The number behind the CSD refers to the size of the dredging pipe that each CSD has in millimetres. The CSDs that company X makes are equipped with a lot of hardware (and software), which Powerspex is providing. Powerspex delivers electrical cabinets and lays cables within the CSDs. The electrical cabinets are all produced in Hengelo in the workplace of Powerspex and the inside of the operating cabin is also connected there in Hengelo. However, the cables that have to be connected in the hull of the vessel are connected in City A, where company X is located. Finally, Powerspex also installs the operating cabin on location.

Figure 1.1:1; A picture of a Cutter Suction Dredger.

1.2 Identified problems

Powerspex identified two areas in which improvements would be desirable. First Powerspex indicated that they would get an extra demand from company X next year, which might pose a problem as Powerspex is now still able to cope with the demand that they are getting from company X, which is the hardware for about 1610 dredgers per year. However, the demand from company X will increase by 30% next year. Accordingly Powerspex will have to produce the hardware for a lot more dredgers and they are not sure if they are able to cope with this extra demand next year. To reach this extra demand a lower throughput time would be desirable. Company X values the on-time delivery very much, because the short lead times for the dredgers makes them stand out from the competition. For this short lead time they need on-time delivery from their suppliers and a lower throughput time can improve the on-time delivery.

The second thing that Powerspex would like to see improved is the number of working hours that is spent on making the dredger hardware. As company X wants to become market leader in the world for the CSDs, they will have to keep their prices low in order to beat the competition. To keep the prices of the company X dredgers low, Powerspex will also have to keep the prices for the dredger hardware low. In order to lower the dredger hardware prices, Powerspex would want to lessen the number of hours spent on a dredger. With lower prices of the hardware Powerspex will also keep itself ahead of its competitors.

1.3 The process

To find out which one of the problems will have to be tackled, the high throughput time or the high number of working hours, I will have to analyse the process first. There is only one problem chosen to tackle, due to time limitations of this research. In order to get to know the 'company X process' within Powerspex I will first need to know some more about the process of producing a dredger at company X. Therefore first the production process of a dredger has been described in Section 1.3.1 to have an idea, after which I have analysed and described the production process within Powerspex in Section 1.3.2. For this latter analysis I have worked in the production for a few days and I have performed interviews with multiple employees of Powerspex.

1.3.1 The process at company X

Before zooming in on the production process of the hardware for a dredger within Powerspex, I will have to know the rough production process of a dredger first. By knowing the rough process of a dredger I will have more insights in what the role of Powerspex is within this process and I will be able to analyse the problem(s) well enough. Therefore to give an idea I have made the process map of the production of an entire dredger with help of the hardware engineer of Powerspex. Within this production of a dredger multiple (external) parties are involved for the cooling pipes, the engine and the hydraulics. Below the process is depicted in a process map in Figure 1.3:1, however the full process map in landscape mode can be found in Section 1 of Appendix A .

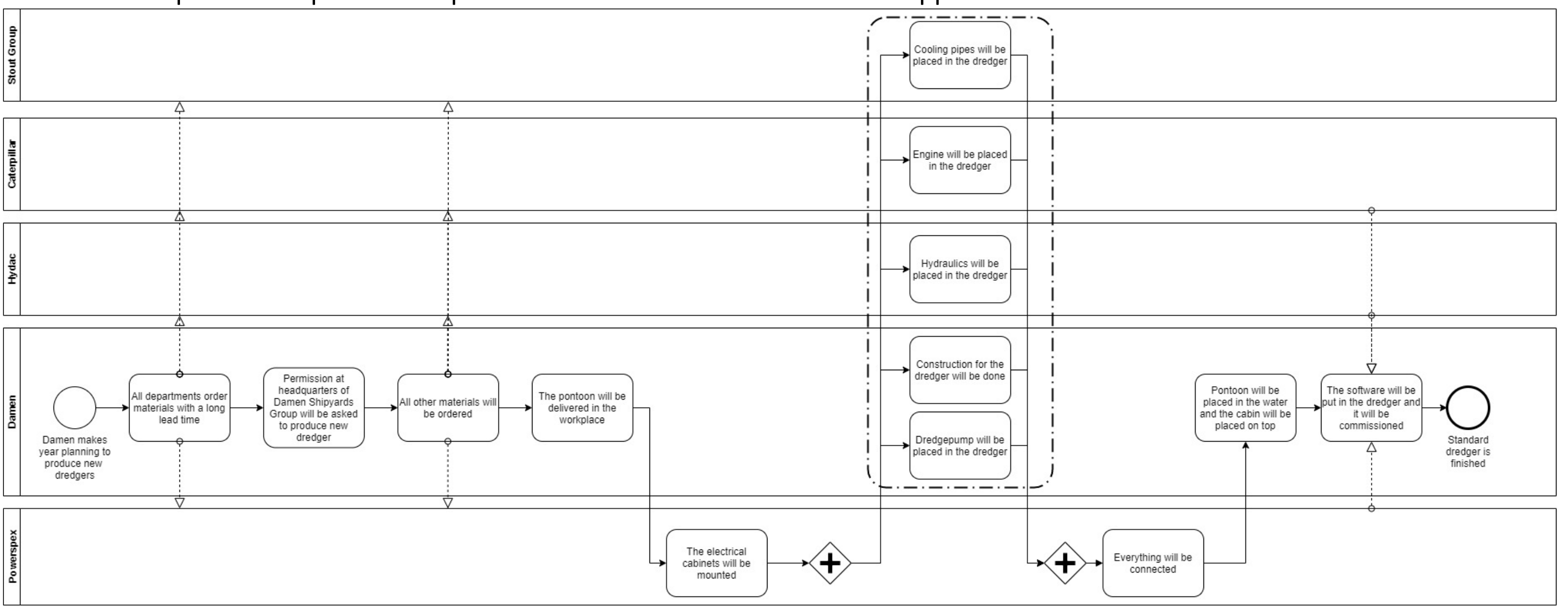

Figure 1.3:1; The process map of the production of an entire dredger

Next I have made a description of the process map of producing a dredger. During the production of a dredger multiple parties are involved, but it is mainly important to understand the entire process, so that the role of Powerspex within it can be identified.

When company X wants to produce a Cutter Suction Dredger the purchasing manager will first start by ordering the products with a rather long lead time, which are amongst others the pontoon, the engine and the pumps of the hydraulics. Then a few weeks later he will start to order the other materials that are needed to produce the dredger, after he has gotten permission from the company Y management. After all the materials are received the pontoon will come in first at company X, this is still just an empty platform that can keep the ship afloat in the water. After both the materials and the pontoon are present the production process will start, when Powerspex will first hang up the electrical cabinets, and the lights so that the other parties can start their operations within the dredger. Then when those parties are as good as done Powerspex will connect all the cables within the dredger and when then the dredger is placed in the water and the cabin is placed on top the commissioning of the dredger will be done. The commissioning is the last test that is executed, in order to test the full functionality of the dredger in its totality.

Now it is clear that when the process starts, company X will first start with ordering the products that have a relatively long delivery time. For Powerspex the operating cabin will then be ordered (because this operating cabin needs to be produced first at a supplier of Powerspex, before the cables can be connected in it). Then the products with a relatively short lead time will need to be produced, which are the electrical cabinets in the case of Powerspex. Then the electrical cabinets will be mounted to the pontoon, after which a lot of other external parties need to install their products. Next Powerspex will need to connect everything, including the operating cabin and finally the software is downloaded in the dredger before it is commissioned by Powerspex and a few other external parties.

1.3.2 The process at Powerspex

The role of Powerspex within the production of a dredger is now more clear, hence I can go deeper into the internal process of Powerspex when producing the hardware for a dredger. Below in Figure 1.3:2 I have mapped out this internal process of Powerspex very roughly and I have given a short description of this process below the Figure again. The entire process map in landscape can be seen in Section 2 of Appendix A. The production process has been composed by asking questions to the hardware engineer for example and by walking within the process.

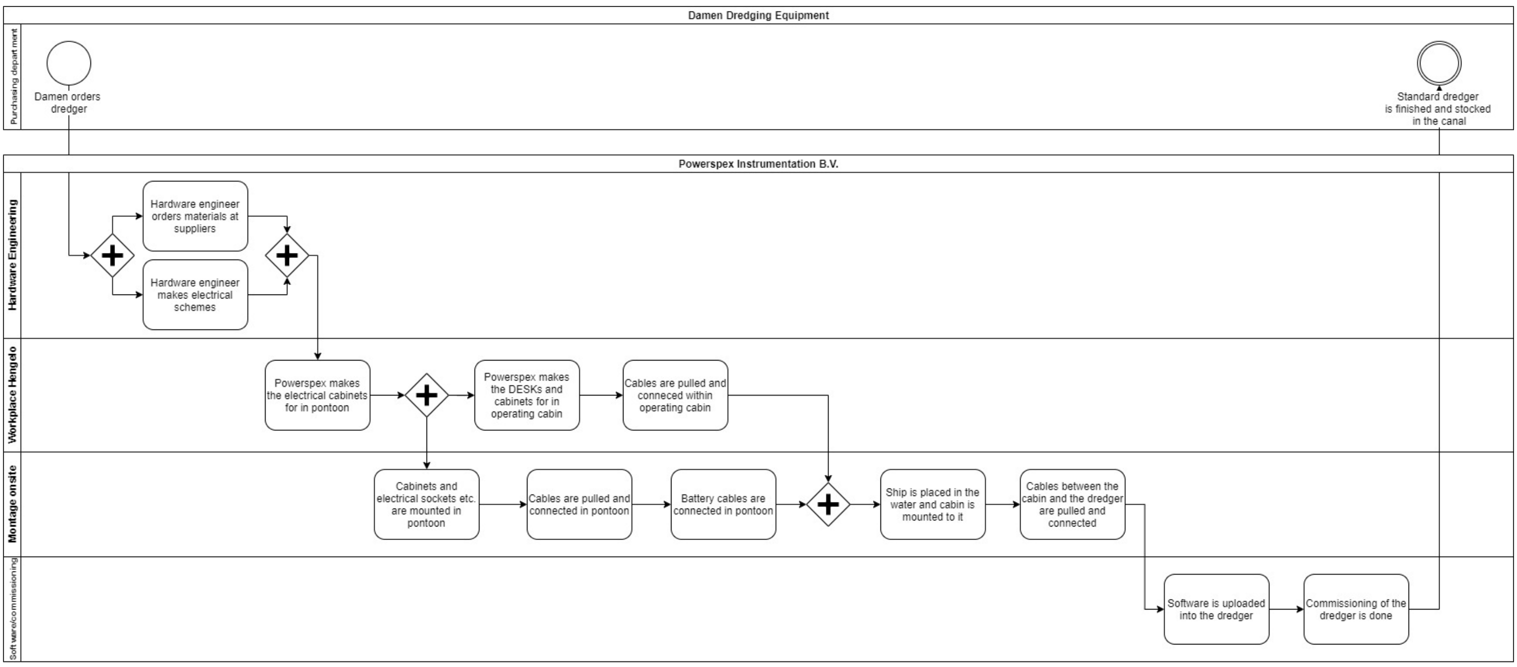

Figure 1.3:2; The overall process map of the production of dredger hardware within Powerspex

The production process of a dredger involves four departments within Powerspex, which are the next ones:

1. The hardware engineering
2. The workplace in Hengelo

3. The assembly onsite in City A
4. The software/commissioning in City A

First the hardware engineer takes care that he makes the electrical schemes and orders the needed materials for all the electrical cabinets and the operating cabin. Then in the workplace the engineers will build and assemble the electrical cabinets according to the electrical schemes. Most of these electrical cabinets will then together go to City A to the assembly onsite and then the next processes at the assembly onsite and in the workplace in Hengelo will start simultaneously:

In City A they will start with mounting these electrical cabinets within the hull of the vessel. After that the cables can be pulled and connected to the electrical cabinets and the other devices that need power supply. Then the employees at the assembly onsite will connect the battery cables within the hull of the vessel, whilst at the same time in Hengelo they will start with building and assembling the electrical cabinet for the operating cabin (SK300) and the DESKs. The electrical cabinet and the DESKs are both needed within the cabin, before the cables will be connected within the operating cabin itself. Once both the cables are connected within the hull of the vessel and the cabin is ready in the workplace in Hengelo the operating cabin will also go to the assembly onsite and will be placed on top of the dredger when it is lifted in the water. Next the operating cabin will be installed and the software will be uploaded into the system of the dredger. When all the previous processes are done the commissioning is done, which is the last test of the dredger at which almost all external parties involved are present.

It can be concluded that the internal process within Powerspex goes as follows when producing the hardware for a dredger: first the hardware engineer will do the preparations for the production process, after which the electrical cabinets are made and the cables are connected in the operating cabin in the workplace in Hengelo. Then the field cables (the cables that will be connected to external components, hence the components that are not provided by Powerspex) will be connected at the assembly onsite, before the software is downloaded into the dredger and the commissioning is done.

1.4 The general problem

Now that I have dived deeper into the two problems that Powerspex had identified in the process, I will analyse both the high number of working hours in Section 1.4.1 and the high throughput time in Section 1.4.2 more thoroughly. I will do this analysis amongst others by estimating both the current throughput time and the current number of working hours. In Section 1.4.3 I will then choose one of the two problems to focus on during this research.

1.4.1 The number of working hours

Powerspex had done a recalculation for the costs that they incurred for a CSD500 (which can be seen as an average dredger). The recalculation considered all the standard CSD500s made within 2019. Within the recalculation a clear distinction had been made again on where the number of hours have been spent within the production process. The distinction is made per department involved in the process, so the total number of hours spent in a department per dredger were registered. However, there is also an extra category added, which is the category of interns, thus the next categories were taken into account within the recalculation:
- Management
- Workplace in Hengelo
- Assembly onsite
- Interns
- Commissioning

The CSD500 is the dredger that is both produced the most and the dredger can be seen as average in terms of the number of hours that are spent on it. The results that have been found when analysing the recalculation are shown below in Table 1.4:1:

Department/function	Average hours spent by this function/department within the process	% of hours spent compared to the total number of hours spent within the process
Management	3435 hours	8%
Workplace Hengelo	10,734 hours	25%
Assembly onsite	19,858 hours	47%
Interns	5,367 hours	13%
Commissioning	2,952 hours	7%

Table 1.4:1; The average number of hours that are spent in each department with the production of a CSD500 in 2019.

Adding up the number of hours spent on the production of the hardware of a CSD500 Powerspex spends about 42,346 hours on one dredger. However, Powerspex would like to spend around 32,202 hours preferably. The service manager of Powerspex thinks that this reduction should be doable within the process moreover, he is striving for a reduction of about 20% within the process.

The hours of the interns are spent in either the workplace in Hengelo or at the assembly onsite in City A. The percentages that are visible in the last column in Table 1.4:1, show that most of the hours are spent in the assembly onsite. After I have asked the employees about their estimates this seemed about right. Furthermore, a lot of hours are spent in the workplace in Hengelo which consumes 25% of the time. When the number of hours spent on a dredger would be diminished, it would be most obvious to do it within the assembly onsite and within the workplace. Within both the assembly onsite and the workplace in Hengelo there is spent about 85% of the total number of hours spent on a dredger. The 85% then includes the hours spent by interns, as the interns are almost always working along with in the assembly onsite or in the workplace in Hengelo.

1.4.2 The throughput time

The throughput time is the time between the moment that an order has been placed and the product is ready for transport (Slack, Brandon-Jones & Johnston, 2016). In this research the throughput time is defined as the time between the moment that company X places the order at Powerspex, until the standard dredger has been commissioned. I have chosen to end the throughput time after the standard dredger has been finished, because this is the last part where Powerspex is working on the production of the dredger, apart from the extra options that will be installed on the ship. The time that the options of the customer are being installed is not taken into account here. The time that it takes for a dredger to have been sold is not relevant and the options that a customer wants on the dredger are very different, which does not make the throughput times of the dredgers comparable. For the throughput times, however I have interviewed the employees for estimates on how long the process takes on average takes. In addition, to the estimates of the employees I have taken a closer look at the progress on the company X planning, which is the planning that Powerspex gets from company X for the next half a year. In the company X planning there is made an overview on which parts of the production process are already finished.

When I was asking the employees about the total throughput time that it takes for a dredger it is rather hard for them to estimate it. The throughput time is difficult to estimate because of multiple reasons. For example next to the fact that the throughput time often differs very much per CSD, there are 5 sorts of sizes (CSD250, CSD350, CSD450, CSD500 and CSD650). Also company X switches the order of priority very often during the process. A very rough estimate from the employees for the throughput time is about 0.19 weeks, of which most of the time is spent at the assembly onsite (they get about 0.05 weeks onsite from company X to finish one dredger).

1.4.3 Research focus

Now I know more about the entire process by having questioned multiple stakeholders within the process, like mechanics E&I at the assembly onsite and production employees in the workplace in Hengelo and I know more about both the problems, the high throughput time and the high number of working hours. With more knowledge on the process and the problems I can make a choice between one of the two problems. The chosen problem will then be further researched to find the causes of the problems and the solutions for it.

Company X values the reduction of the lead times of the products of all suppliers, because their customers again want the lead times of the dredgers to be as short as possible. However, Powerspex is not the only supplier of products for the dredgers and a lot of other suppliers have longer lead times for the dredger parts than Powerspex has with their parts. Therefore improving the throughput time is considered less of a priority than the number of working hours within the production.

When the number of working hours will be reduced the results can be seen immediately. In addition, to this, reducing the number of working hours within the production process might also result in an improved throughput time. So due to the longer lead times of the products of other suppliers and the fact that fewer working hours might result in a lower throughput time, it has been decided to further research the production process by putting the focus on the number of working hours that are put into one dredger.

To lessen the number of working hours the process will be taken a look at from a lean perspective. Lean has been chosen as perspective, because Powerspex prefers this method of optimization, as Lean has proven to be an effective method of optimization.

From now on the focus in the thesis will be on reducing the number of working hours within the production process of making the dredger hardware within Powerspex from a lean perspective. The high number of working hours is the general problem of this research. During the research I will be diving deeper into the causes of the high number of working hours, so that I can both make a problem cluster and identify the root cause(s). The problem cluster and the root causes will therefore be discussed in Section 4.2.5.

1.5 Methodology

To work towards a solutions I have chosen a systematic approach available in the literature, which is described in Section 1.5.1. The lean perspective is elaborated on in Section 1.5.2 and the limitations of the scope of this research are discussed in Section 1.5.3.

1.5.1 The MPSM

In order to eliminate the waste within the process of Powerspex via a systematic way, I have chosen a methodology to tackle this problem. The methodology that has been chosen is the Managerial Problem Solving Method (MPSM) (Heerkens, Van Winden & Tjooitink, 2017). The MPSM consists out of seven steps, of which I will perform 5 steps within this research. The first step of the MPSM I have already done, which is identifying the problem. The problem namely is the number of working hours that has to be reduced. The next Phase of the MPSM then is formulating the approach, which will be done in this chapter. In Phase 3 I will then analyse the problem, before I will think of alternative solutions in Phase 4. Finally, I will assess the solutions in Phase 5.

1.5.2 Lean

In Section 1.4.3 I have explained why a lean perspective is used in this research, however I still have to elaborate on how I am applying the lean perspective in this research. A short explanation can be read here, however for more information I refer to Chapter 2 where the theoretical framework will be explained. Lean contains a method that looks at the activities within the process and subdivides the activities within the process in value adding activities, non-value adding activities and required non-value adding activities (Wang, Conboy & Cawly, 2012). Non-value adding activities are considered waste within Lean and will have to be removed from the process, in order to optimize the operations performance (Shashi, Centobelli, Cerchione & Singh, 2019). Waste is considered everything that is not needed to get the job done (Bicheno & Holweg, 2016) and a required non-value adding is needed under the current circumstances, so it cannot be completely eliminated from the process (Tyagia, et al., 2015; Dombrowski, Schmidt & Schmidten, 2015). The lean method of eliminating non-value adding activities from the process will also be used in this research.

1.5.3 Limitations of the scope

Before the problem approach will be explained to lessen the number of working hours it would be good to mention that there is already another intern that is working at Powerspex who is currently busy with researching the redesign of the warehouse. Therefore the redesign of the workplace in Hengelo falls outside of the scope of this research. Company X is currently also busy with developing a revised version of a dredger together with all parties involved in the production process of the CSDs, among which Powerspex. Due to the development of this revised version, which is called the company X 2.0, some processes will be subject to change already during the time this research is performed.

1.6 Main research question

The research focus, that is discussed in Section 1.4.3, is on reducing the number of working hours within the production process when taking in mind a lean perspective. Therefore the next main research question has been drafted for Phase 2 of the MPSM:

'*How can Powerspex reduce the number of working hours for the production of a dredger by improving the (production) process from a lean perspective?'*

1.7 Research questions

To properly answer the main research question: '*How can Powerspex reduce the number of working hours for the production of a dredger by improving the (production) process from a lean perspective?*', multiple sub-questions will be needed. First I will have to know more about the production process when Powerspex makes the dredger hardware. To get to know the process I have drafted 2 research questions.

RQ1; Visualization of the process

First the entire process of Powerspex will have to be known, to know what each part of the process contributes to the value of the product, which would lead to the next research question:

1. *What does the entire process of Powerspex look like when producing the hardware for a dredger?*

In order to answer this first research question, the entire process will be mapped out. To map the processes, I will first gather more information on the process. Within the entire production process of dredger hardware there are four departments involved, as described in Section 1.3.2. I will observe the processes in the next three departments: hardware engineering, the workplace in

Hengelo and the assembly onsite. Next to observing the processes I will also ask questions during the observations, which I am doing, because the choice of the employees to do some activities in a particular way will have to be clear to me. I will not observe the commissioning process, because the process is relatively short and the number of hours spent on the commissioning is often dependent on the quality of the hardware (and the software) within the dredger. Therefore I will hold an interview with the field service manager of Powerspex.

To increase the reliability of the answer to this research question I will use experienced employees (employees who have more than two years of working experience within Powerspex) for the observations and for asking the questions.

To map the processes I will use the BPMN2.0 language. The reason for using this modelling language is explained in Appendix B together with the explanation of the modelling language itself.

RQ2; Activity times
With the process known I will need to know how long each activity takes within the production process. The time that each activity takes will have to be known, because when the number of hours will be reduced there will have to be known where in the process these hours occur exactly. Also the time measurements indicate the degree of importance of removing the specific non-value adding activity from the process (at least for most of the processes then). Hence the following research question:

2. *How much time is spent on each part of the production process?*

To answer this question I will use both the sub processes into which the production process was divided in research question 1 and the activities that are identified in the answer to research question 1. In order to get the numbers on how long each activity in the sub process takes, I will ask the employees for their estimations. Although measuring by asking the employees for their estimates may be a threat to the reliability of the results, this is the best way given the fact that most of the processes take up a very long time, so that a reliable measurement cannot be executed. For the processes of the hardware engineer I will only ask the hardware engineer himself for his estimations, as he is the only one that has insight within this process. In addition, to this, within the workplace in Hengelo I will ask the production supervisor, together with one production employee, to have a higher reliability of the processing times. For the assembly onsite I will ask the supervisor there for his estimations together with another mechanic E&I. Finally for the commissioning, I will ask the software engineer for his estimations together with the field service manager. All of these employees also have more than two years of working experience within Powerspex, to keep the quality and the reliability of the measurements as high as possible.

RQ3; ((required) non-)value adding activities
As the activities within the process are known, I will have to find out which activities can be labelled non-value adding and non-value adding, but required. First the activities that can be labelled as non-value adding will have to be known, after which the required non-value adding activities can be found. In order to find the non-value adding activities, the value adding activities will have to be known. Next the required non-value adding activities will have to be found, because these activities cannot be (fully) eliminated from the process, whilst the plain non-value adding activities can be fully eliminated. So by finding these required non-value adding activities I can distinguish the activities that cannot be fully eliminated from the process. The next research question is needed to find the (required) non-value adding activities of the process:

3. *What activities in the production process can be considered non-value adding for company X?*

Lean looks at the process from the perspective of the customer to identify the value adding activities. So in order to know where Powerspex adds value to the product and service of company X, I will hold an interview with the purchasing manager of company X. The purchasing manager of company X has been chosen as the interview subject, because he is the one paying for the products in the end and because he has more knowledge to how company X values its suppliers. Therefore asking the purchasing manager is considered a better option than asking a sales employee from Powerspex for example. Misperception of the customers value is often a cause for non-value adding activities within a process (Slack, Brandon-Jones & Johnston, 2016). Next I will distinguish the required non-value adding activities by using the theoretical framework. Within the theoretical framework a literature research will be done to define (required) non-value adding activities. I will use a literature research to identify these required activities as this will help to objectify the definition of required non-value adding activities. By using literature I can make sure that the required non-value adding activities can be assessed as objectively as possible and nothing can be overlooked or too easily characterized as a required non-value adding activity. When the definition of a required non-value adding activity is clear I will identify these within the current 'company X process' within Powerspex. Within this research I will first try to focus on eliminating or reducing the number of working hours spent on the non-value adding activities. If there is time left, then I will also look if the required non-value adding activities can be eliminated or reduced as much as possible.

RQ4; Lean wastes

Once it is known what activities can be considered value adding I will have to search the lean wastes that can be connected to the non-value adding activities. Knowing the lean waste that can be connected to the non-value adding activity can help to find the causes of the non-value adding activity. After the lean wastes are found within the theoretical framework the lean theory will have to be linked to the non-value adding activities, this makes the next research question:

4. *What lean wastes can be linked to the non-value adding activities found within the current 'company X process' within Powerspex?*

To find the lean wastes connected to the current non-value adding activities within the production process, I will use the literature research that I have performed and have described in the theoretical framework (Chapter 2). Within this theoretical framework the most important lean wastes are also further explained. The non-value adding activities, found by using the answers to research question 1 and 3, will then be linked to the wastes that are found in the lean theory. The lean theory will then be applied within this research and more insights will be gained into the causes of the non-value adding activities within the current production process.

RQ5; causes of the non-value adding activities

Finally, once the non-value adding activities are identified I will have to know how they can be eliminated successfully. However, to be able to eliminate the non-value adding activities I will first have to go deeper into the causes of these non-value adding activities first. By going deeper into the causes of the non-value adding activities I can make a list of the root causes that are causing the non-value adding activities, and when these are solved the non-value adding activities can be either eliminated within the process or the time spent on those activities can be reduced. To find the causes and the root causes of the non-value adding activities I have drafted the next research question:

5. *What are the (root) causes of the non-value adding activities within the current production process of Powerspex?*

After the non-value adding activities that cause an unnecessarily significant increase of the number of working hours within the production process are identified, I will work towards a solution. In order to work towards this solution I will analyse all non-value adding activities and all the encountered causes of these non-value adding activities within the production process of making the dredger hardware. To find the causes of the non-value adding activities I will use my experience within the process and talk with multiple employees of Powerspex, if needed, to find all the causes to all the problems. With the causes that I have found I will make a problem cluster in which the root causes of the non-value adding activities can be identified.

RQ6; Alternative solutions
If all the (root) causes of non-value adding activities have been identified, there will have to be thought of solutions by me and some stakeholders. The solutions will have to make it possible for Powerspex to either eliminate the non-value adding activity or to reduce the time spent on the non-value adding activity. Next the solutions will have to be analysed for their (dis)advantages, so that a proper recommendation can be made. The next research question will help me to find and assess the possible solutions:

6. *How can the non-value adding activities be eliminated or the number of hours spent on it be reduced as much as possible?*
    a. *What are possible solutions to either eliminate or reduce the time spent on non-value adding activities?*
    b. *How much benefit can Powerspex get out of each solution, compared to the costs and other disadvantages that come with each solution?*

To find and evaluate possible solutions I will schedule a group session with myself and the most important stakeholders. I consider the next stakeholders the most important ones for the 'company X process' within Powerspex: the production supervisor of Hengelo, the hardware engineer, the onsite supervisor, the field service manager, and possibly the service manager. However, to make it a useful group session I will first have to be able to suggest some possible solutions, otherwise it might be hard for employees to come up with solutions themselves on the spot. To find possible solutions before the group session I will: use one-to-one discussions with some stakeholders in the process, search on the internet and use logical reasoning. The group session is considered useful, because then the consequences of the solutions for the entire production process can be thought through. By thinking through the consequences of the solutions for the entire process it is prevented that a solution benefits only one part of the process, whilst it involves many extra hours, hence costs at the other part (6a).

To assess the solutions for their effectivity the number saved hours within the production process will have to be calculated with each solution. To calculate the number of saved hours I will use the estimates of how long each process takes (which is the answer to research question 2) and the results from the group session. Moreover, when needed I will ask the concerning employees for accurate estimates about how much time they expect that a specific solution will save them. However, the disadvantages should also be considered when choosing a solution. With the number of saved hours, the investment costs and other disadvantages, a multiple-criteria decision analysis will be done (6b).

RQ7; Evaluating and implementing solutions
When the solutions have been evaluated I will have to consider how the solutions should be implemented and evaluated within the current production process of Powerspex. For this I have setup a research question with two sub-questions again, namely:

7. *How can the solutions be implemented and evaluated within the current production process?*

a. *What steps are needed to successfully implement each solution in the current production process?*
b. *How can the management of Powerspex effectively evaluate the (implementation of the) solutions?*

After one or multiple solutions are recommended, it cannot be implemented due to time limits of this research. However, an implementation plan of the solution will then be presented to Powerspex, so that the solution can be implemented within the production process successfully (7a).

To evaluate the performance of the production process after the solutions have been (successfully) implemented I will make a tool. The tool will enable the management of Powerspex to analyse the performance of the process and the effect that the solutions have. The effect will be measured in multiple ways, so the tool will also have to be able to show the effect of the solutions on the (purchasing) costs (7b).

1.8 Intended deliverables

At the end of this graduation assignment a full report with the entire research will be delivered, together with an end presentation to present the most important findings. Next to the full report and the end presentation a process map of the entire production and the time measurements will be given to Powerspex, so that they can use that information for their planning and to implement continuous improvements within their production, if possible. The implementation plan will also be delivered to Powerspex, by discussing this plan in both the end presentation and by delivering it written on paper. Finally, a dashboard will be given to Powerspex, so they can measure the performance of the operations after the solutions have been implemented.

1.9 Conclusion

The Managerial Problem Solving Method will be used within this research, of which I will perform the first 5 Phases. For the research I will first dive deeper into the process, by observing the process and asking questions. Then I will identify the wastes within the current production process of producing dredger hardware within Powerspex, amongst others by interviewing the purchasing manager of company X and using a literature research on Lean. Furthermore, the problems causing the non-value adding activities will be analysed before solutions will be thought of, partly by having a group session with the most important stakeholders from the perspective of Powerspex. Finally, the solutions will be analysed for their advantages and disadvantages and an implementation plan will be made, if necessary. When I have answered all of the research questions I can answer the main research question: *'How can Powerspex reduce the number of working hours for the production of a dredger by improving the (production) process from a lean perspective?'*. In the conclusion I will argue the best solutions for each of the identified problems. Then I will also make a recommendation towards the management of Powerspex, for which I will use the conclusions to the main research question.

2 Theoretical framework

The methodology and the research questions are setup. Now before I will analyse the process, I will first have to be perform a literature research to know what Lean actually is and how it can be used in this research. In Section 2.1 I will define the term Lean, before I will describe the wastes that Lean identifies in Section 2.2. Next the 7 original wastes of Lean, that are classified as muda are discussed in Section 2.3, before the new wastes of Lean are described in Section 2.4. In Section 2.5 the definition of the (required) non-value adding activities will be discussed, so I can identify these activities when the entire process of producing the dredger hardware within Powerspex is clear. Finally, a conclusion of the lean framework will be given in Section 2.6.

2.1 Defining Lean

Lean is considered a very broad concept on which there is still no complete consensus on what it actually means and on what can be considered a characteristic of Lean (Hu, Mason, Williams & Found, 2015). However, in order to clarify the lean concept; it can be used in three different, but somehow related perspectives (Slack, Brandon-Jones & Johnston, 2016).

- First, Lean is used as a philosophy on how to run the operations, in which the usage of lean synchronization is centralized. Lean synchronization focusses on smoothing the flow through the processes, with the elimination of all the wastes. The lean philosophy on how to run operations covers three key issues: the involvement of all staff, the strive for continuous improvement and the elimination of waste.
- The second usage of Lean focusses on Lean as a method of planning and controlling the operations. The usage of Lean as method of planning and controlling operations mainly focusses on how a smooth flow through the processes can be managed, which includes for example Kanban that is a system designed to establish a pull control within the operations.
- The third and last usage of Lean is as an improvement for operations performance. The third usage of Lean is known for the set of techniques and tools to help eliminate the waste from the operations.

As Lean is divided into multiple categories a theoretical model has been made and is shown below in Figure 2.1:1.

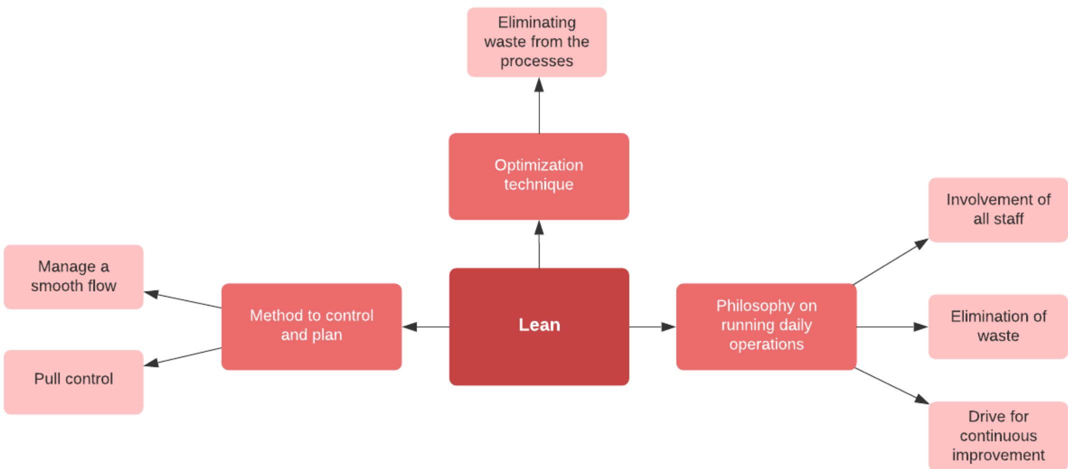

Figure 2.1:1; The theoretical model of the Lean concept.

One of the things on which Lean focusses is the elimination of waste within the process. It looks at the process from the perspective of the customer to identify the just mentioned waste, this waste will then be eliminated in order to optimize the process.

2.2 Muda, mura, muri

Within the lean theory there are three causes of waste identified within a process, which are *muda*, *mura* and *muri* (Slack, Brandon-Jones & Johnston, 2016). *Muda* looks at the process and identifies wasteful activities within the process, whereas *mura* identifies the lack of consistency within the process and *muri* looks at unreasonable requirements that are put on a process. For this research, however the *muda* is the one that will be looked at, as this one looks at non-value adding activities within the process. Then the following causes of waste are identified: overproduction, waiting time, transportation, process inefficiencies, excess inventory, wasted motion, and defects (Arunagiri & Gnanavelbabu, 2014).

2.3 The original 7 wastes

Overproduction

The first type of *Muda*, as named within the lean theory, is the overproduction. Overproduction means that as a supplier you are producing more than your customers are asking for, this can also be done internally however. For example when the next process in the operations is not producing as fast as the previous one, whereas the previous process keeps producing at full pace (Arunagiri & Gnanavelbabu, 2014). Overproduction occurs when there is made too much, too soon or just-in-case, whereas the goal of Lean is to produce exactly what is needed at the time that it is needed (Bicheno & Holweg, 2016). When there is overproduced it will lead to both unnecessarily long lead times and unnecessarily high capacity (Sivaraman, Nithyanandhan, Lakshminarasimhan, Manikandan & Saifudheen, 2020). By introducing a pull-system, this overproduction can be prevented, this means that the products are only produced when the customers are ordering them which can also be done internally. Then the next process will have to be considered a customer (Arunagiri & Gnanavelbabu, 2014).

Waiting time

Waiting time can be caused by amongst others processing delays or machine downtimes. Waiting time actually occurs if there is a difference between the operator's time allocation and the allocation of the actual processing time. So when there is a difference between the actual processing time and the working time of the operator, waiting time has occurred (Arunagiri & Gnanavelbabu, 2014).

Transportation

Transportation can occur both in and outside of the facility. Outside of the facility means the transportation to a customer and the transportation from a supplier, whereas inside of the facility transportation can occur between different work stations or departments. As the products then will have to be stored in the warehouse before continuing to be processed (Arunagiri & Gnanavelbabu, 2014). Unnecessary transportation can sometimes occur internally when the floor layout is rather inefficient, because a product sometimes has to be transported up and down a lot in the facility due to the fact that the product does not follow a logical pathway (Blijleven, Koelemeijer & Jaspers, 2017). On the external transportation the supply chain has a big effect, namely sourcing materials from suppliers located close to the company can save a lot of transportation (costs) (Arunagiri & Gnanavelbabu, 2014).

Overprocessing

Waste of overprocessing and complexity (or process inefficiencies) is often overlooked by companies, as they fail to recognize it as a waste (Arunagiri & Gnanavelbabu, 2014). Overprocessing is simply spending more time to activities or processes than the customer actually requires (Blijleven, Koelemeijer & Jaspers, 2017; Kaswan & Rathi, 2020; Sivaraman et al., 2020; Arunagiri & Gnanavelbabu, 2014). Within the process a lot of processes are performed which do not all add value to the product or service, especially with complex processes there will reveal unnecessary steps within the process. In this case, carefully assess activities to see if they add value for the customer or if they can be done automatically (Arunagiri & Gnanavelbabu, 2014).

Excess inventory

Too much inventory that is stocked is also considered a waste within Lean (Arunagiri & Gnanavelbabu, 2014). Too much inventory is a threat for the productivity and the quality of the products, because inventory amongst others leads to the fact that problems cannot be identified quickly (Bicheno & Holweg, 2016). Inventory also requires quite some capital, however it is not delivering any returns. A lot of inventory will require a bigger warehouse which will again lead to higher handling costs, because it costs more time to store the products in inventory. In addition, to higher handling costs a lot of stock will also lead to more obsolete and damaged products in inventory. By streamlining processes and reducing lead times excessive inventory can be prevented (Arunagiri & Gnanavelbabu, 2014).

Wastes of motion

Wastes of motion occur if the employees make unnecessary movements within the process, that will lead to processing delays (Arunagiri & Gnanavelbabu, 2014). The wastes of motion also often come forth out of an inefficient layout, however this inefficient layout is not always the cause of wastes of motion, as this waste includes any unnecessary physical activity (Sivaraman, et al., 2020; Francis & Thomas, 2020; Bicheno & Holweg, 2016). Too many wastes of motion first affect the employee, however afterwards too many wastes of motion can also have its effects on the product quality and on the customer (Bicheno & Holweg, 2016).

Defects and errors

Defects and errors within a process are also considered a waste, as these defects will often lead to rework, inspections, process changes and machine downtimes. Defects and errors as a source of waste is often under reported as it not only incurs direct costs, but also indirect costs (Arunagiri & Gnanavelbabu, 2014). The direct costs incurred are the material costs and the rework costs, these costs are caused by internal failures. However, the long term costs are caused by external failures and lead to extra costs by for example after sales service, warranty and lost custom. (Arunagiri & Gnanavelbabu, 2014; Bicheno & Holweg, 2016).

2.4 New wastes

Bicheno & Holweg (2016) argue that besides these 7 original Lean wastes there can be more identified. The other waste that is identified the most is the underutilization of skills and talent, which refers to the skills and talents of the employees that are either not used to the fullest extent or even misused (Kaswan & Rathi, 2020; Blijleven, Koelemeijer & Jaspers, 2017).

The other wastes defined by Bicheno & Holweg (2016) are the next ones: the waste of making the wrong product efficiently, excessive information and communication, the waste of time, the waste of inappropriate systems, the waste of water and energy, the waste of natural resources, the waste of ‘no follow through’, the waste of knowledge and the waste of empty labour. These wastes will however not all be further discussed during this research, partly because of the fact that some of these new lean wastes can be linked to the original ones in some way (Bicheno & Holweg, 2016).

2.5 Value adding and (required) non-value adding activities

Lean considers three kinds of activities within a process (Wang, Conboy & Cawly, 2012):

1. Value adding activities
2. Non-value adding activities, however required
3. Non-value adding activities

Non-value adding activities

By identifying the non-value adding activities within a process and eliminating these activities, the operations and performance of an organization can be optimized (Shashi, Centobelli, Cerchione & Singh, 2019).

According to Bicheno and Holweg (2016) an activity is value adding when the customer is prepared to pay for it and the product is transformed. An activity is only considered transforming when it adds anything to the form, fit or functionality of the product or service, otherwise it is considered waste. Waste is considered every activity that is not needed to get the job done, hence an activity that is not done the first time right is an example of a non-value adding activity.

Required non-value adding activities

Then amongst these non-value adding activities there might be some activities that are required. Required non-value adding activities are activities that do not really add value for the customer, hence the customer is not really willing to pay for it and these activities also do not add something to the product (Tyagia, Choudhary, Cai & Yanga, 2015). But these processes are necessary under the current circumstances, so these activities cannot be completely removed. However, these activities can be held to a minimum. So the time that these activities take up are to be made as efficient as possible (Tyagia, et al., 2015; Dombrowski, Schmidt & Schmidten, 2015).

2.6 Conclusion lean framework

Lean is a concept that is widely used, as it is used as a method to run the operations, as a method for planning and controlling the operations and as a set of tools to optimize the operations performance. Lean identifies wastes within a process and tries to eliminate these wastes. The wastes that Lean identifies are *Muda*, *Mura* and *Muri*. Lean subdivides the *Muda* again in the next 7 original wastes: overproduction, waiting time, transportation, overprocessing, excess inventory, waste of motion and defects and errors. Currently there are also new wastes identified of which the most important one is the waste of skills and talents. Finally, Lean identified three kinds of activities within a process. From the three activities the non-value adding activities should be removed to optimize the performance of an operation. A non-value adding activity is every activity that both does not contribute to the transformation of a product and for which the customer does not want to pay. A required non-value adding activity is necessary, not for the customer, but under the current circumstances.

3 Process analysis

Within this chapter the process will have to be more clear. First the process will be subdivided in sub-processes and will be mapped out in Section 3.1 of this chapter. Then the time that each activity takes, according to the estimates of the employees will be given in Section 3.2, before the value of company X will be discussed in Section 3.3 together with the (required) non-value adding activities.

3.1 RQ1; Process visualization

To answer the next research question: 'What does the entire process of Powerspex look like when producing the hardware for a dredger?' I will visualize all the activities that are taking place within the process. For the process visualization I have chosen the method of BPMN2.0, supported by the literature research described in Appendix B; the theoretical framework. The process has been separated in different activities first, after which the different activities are described and mapped out.

The (production) process of Powerspex has been visualized very roughly already in Section 1.3.2, hence this is already clear. The process map, visualized in Figure 1.3:2 will now be used to divide the process into smaller sub-processes, which leads to the next sub-processes:

1. The preparation of the production process.
2. The production of the electrical cabinets.
3. The preparation of cabling the operating cabin.
4. Cabling the operating cabin.
5. Preparing the cabling on the assembly onsite.
6. Cabling within the hull of the vessel.
7. Cabling between the operating cabin and the pontoon.
8. Commissioning the dredger (including uploading the software).

As there are 5 types of dredgers that are produced within company X, I will have to choose for which type of dredger the process map will be made (although they are almost the same they differ a bit sometimes) and for which one the number of hours will be measured. Therefore I have chosen to use the CSD500 for both making the process maps and measuring the number of hours it takes to produce a dredger. I have chosen the CSD500 due to two reasons. First, the CSD500 is the dredger that is sold the most (hence also produced the most). Second, because the CSD500 can be seen as an 'average dredger' given the amount of work it is compared to the other 4 types of dredgers.

All 8 parts of the processes, as divided above, will be mapped out below. For the BPMN-modelling language an extensive explanation is given in Appendix B. In addition, a full horizontal placed map of each process is given in the appendices in Appendix A, from Section 9.1.3 until Section 9.1.11.

Preparation production process

First the hardware engineer will have to prepare the process, by ordering the materials and printing the electrical schemes amongst others. Also the materials will have to be booked in by the warehouse manager of Powerspex before the electrical cabinets can be produced. The full process can be seen below in Figure 3.1:1.

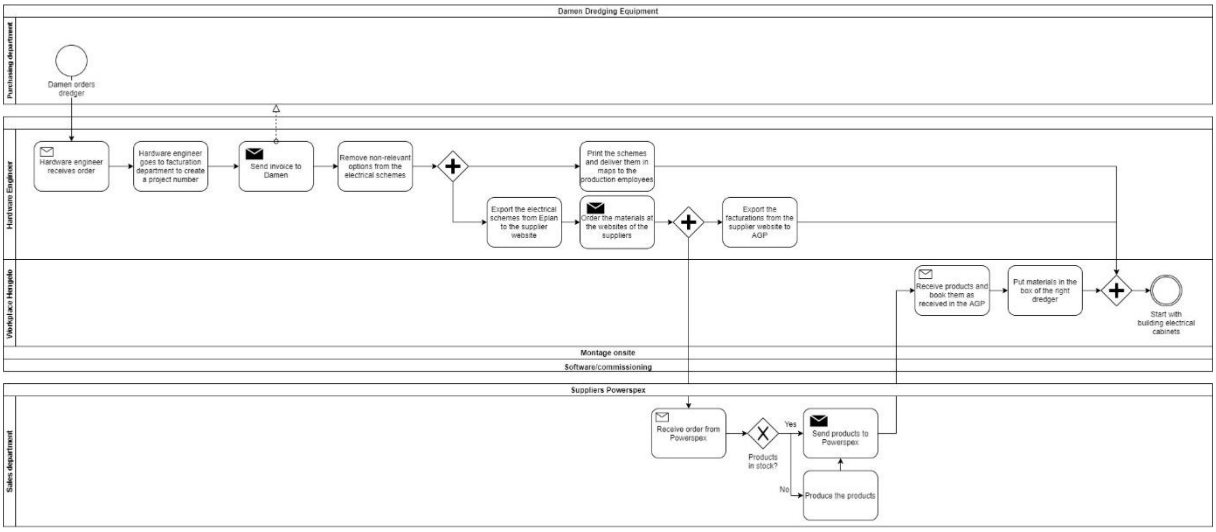

Figure 3.1:1; The process map of the preparation of the production process.

Production electrical cabinets

After the process is prepared, the employees of Powerspex in the workplace in Hengelo can start to produce the electrical cabinets. For each dredger some electrical cabinets will have to be hung up within the hull of the vessel, hence these cabinets will have to be produced first. For the CSD500 these are the SK100, the SK200 and the SK250. Below in Figure 3.1:2 the entire process is mapped out.

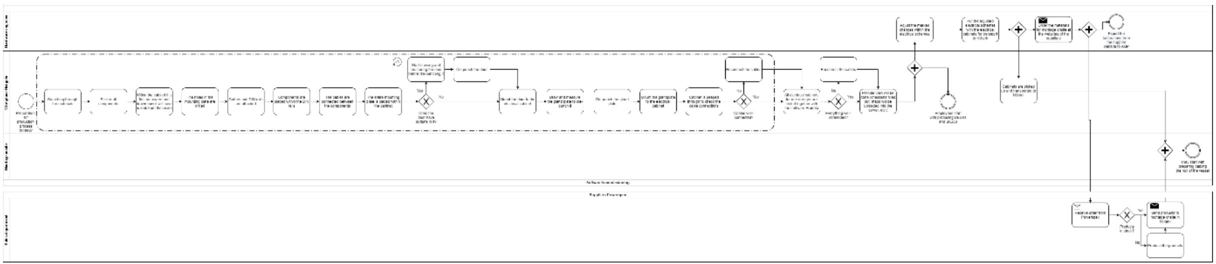

Figure 3.1:2; The process map of the production of the electrical cabinets.

Preparation cabling operating cabin

To cable the cabin an electrical cabinet for in the cabin and two DESKs will have to be produced first. For the CSD500 the 2 DESKs are the DESK300 and the DESK400. The electrical cabinet needed for the cabin of the CSD500 is the SK300. Below the entire process is visualized in Figure 3.1:3.

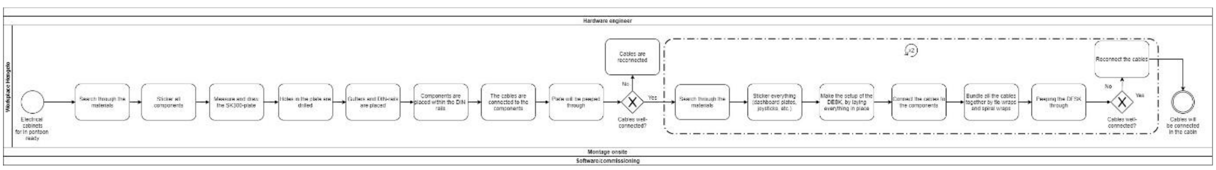

Figure 3.1:3; The process map of the preparation of cabling the operating cabin.

Cabling operating cabin

Next the cables in the operating cabin are connected. Most of the cables are connected from and towards the SK300, the DESK300 and the DESK400. In Figure 3.1:4, which is the figure below, the process is mapped out.

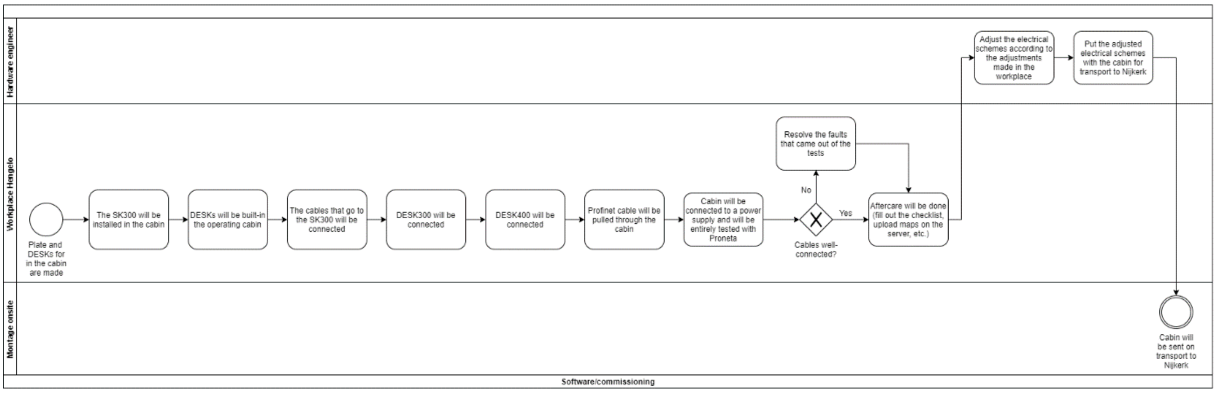

Figure 3.1:4; The process map of cabling the operating cabin.

Preparing cabling at assembly onsite

The electrical cabinets that are finished are needed amongst others to complete this process. The hull of the vessel will be prepared, so that when all other parties are finished the employees at the assembly onsite can immediately start pulling and bundling the cables. Below the entire process of the preparation is visualized in Figure 3.1:5.

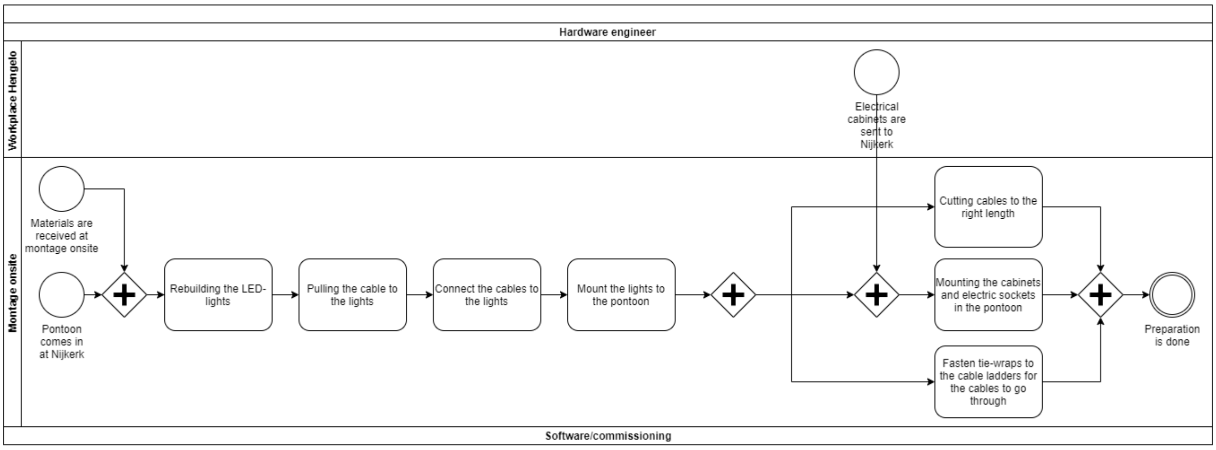

Figure 3.1:5; The process map of preparing the cabling at the assembly onsite.

Cabling within the hull of the vessel

Once all other external parties are as good as finished with their parts within the hull of the vessel Powerspex will start to pull, bundle and connect the cables. Powerspex will do the pulling, bundling and connecting of the cables for each of the three electrical cabinets, not yet considering the battery cables that have to be connected afterwards. The full process can be seen below in Figure 3.1:6.

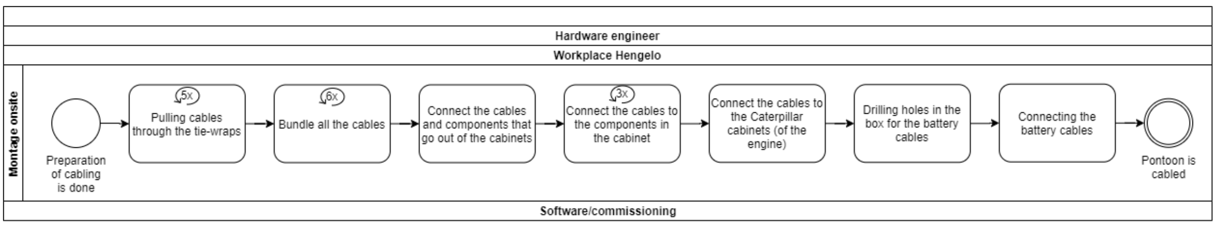

Figure 3.1:6; The process map of cabling within the hull of the vessel.

Cabling between operating cabin and pontoon

The operating cabin that will be placed on the dredger, will have to be (electrically) connected to the hull of the vessel. Therefore a Roxtec will be used amongst others to make the holes through which the cables are going waterproof. The entire process is visualized below in Figure 3.1:7.

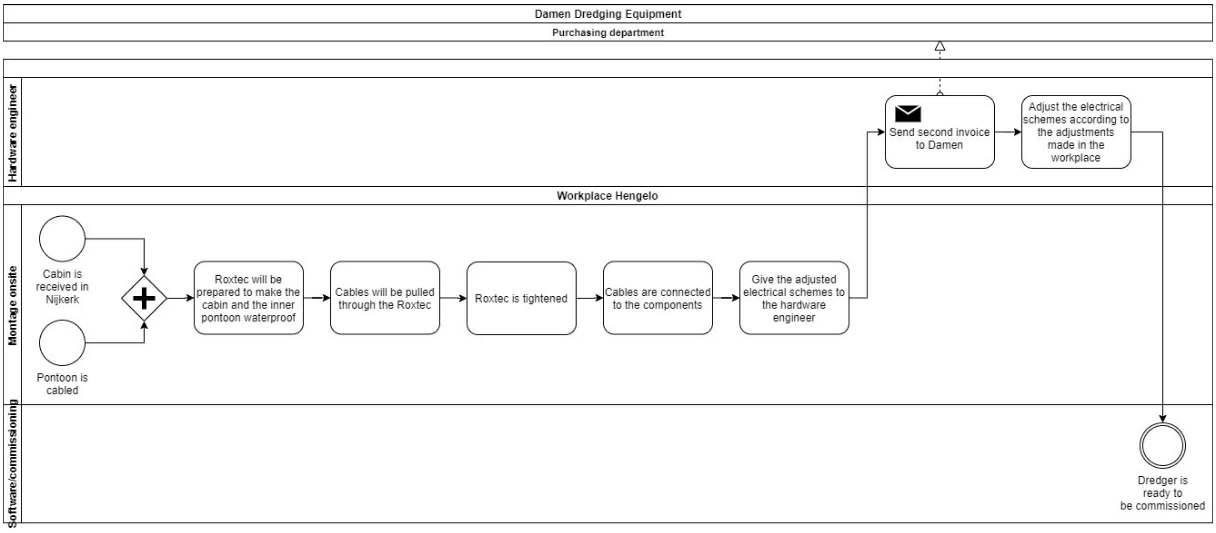

Figure 3.1:7; The process map of cabling between the operating cabin and the pontoon.

Commissioning dredger

For this process I have held an interview with the field service manager of Powerspex. When all processes are finished the dredger can be commissioned and the software can be downloaded into the system of the dredger. When the final test is finished the standard dredger is finished and it is ready to be sold to a customer. The full process can be seen below in Figure 3.1:8.

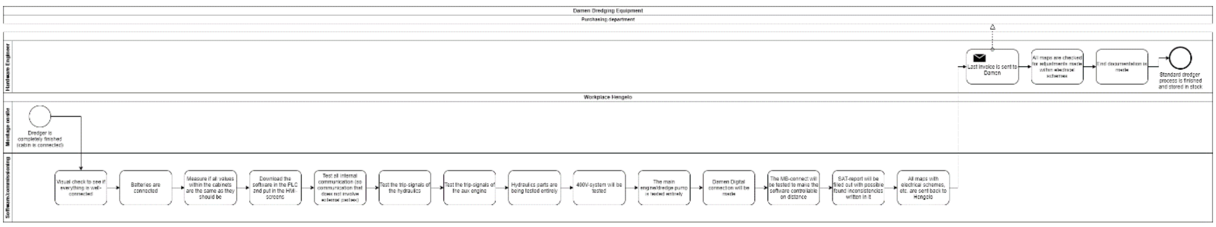

Figure 3.1:8; The process map of commissioning the dredger.

Conclusion

The activities needed to finish all of the 8 sub-processes are clear and the entire production process of the dredger hardware contains quite some activities. Each block within the processing maps represents an activity. All mapped out activities will be will be analysed for the time they take and their added value within the process.

3.2 RQ2; Activity times

The activities performed within the process are clear, hence the next research question will have to be answered in this section: 'How much time is spent on each part of the production process?'. To know how many hours are spent in each part of the process the answer to research question 1, which is written above in Section 3.1, is used to answer this research question. First in Section 3.2.1 the methodology of the measurements are given, before the estimates of the activity times are given of each sub-process in Section 3.2.2. In Section 3.2.2 a short description will be given before the table is given with the estimates of the activity times. Next, I will compare the number of hours spent within the process according to the estimates of the employees to the total average number of hours

(42,346 hours) spent within the process in Section 3.2.3. Finally, a conclusion will be given in Section 3.2.4.

3.2.1 Methodology

In order to estimate the number of hours spent on each activity, I have asked employees of Powerspex. The function of the employees from which the estimates have been received are noted in the second row of the Tables: 3.2:1 until 3.2:8. In every department the supervisors have given me the estimates. To increase the reliability of the estimates I wanted to ask at least two employees for every activity however, this was not possible due to multiple reasons. The Covid-19 situation and the absence of a lot of employees during the summer months made it difficult to get multiple estimates.

3.2.2 Activity times

In each of the Tables 3.2:1 until 3.2:8 the activity is described in the left column or the second-left column, depending on if the concerning electrical cabinet is indicated in the table. The estimations of the times are noted in hours in the next columns and in the light blue row the employee from which the estimate came is indicated.

Preparation production process

The activities of receiving and booking in the products in AGP and putting the materials in the right project box are not considered, as these activities are done by the warehouse manager of Powerspex. The warehouse manager never registers his hours on specific projects, but his hours are considered overhead costs. Therefore I will also not take into account these activities when assessing for non-value adding activities. The time that each activity takes for this sub-process is visible in Table 3.2:1.

Process	Time estimations (hours)	
	Hardware engineer	Warehouse manager
Create project number	4	
Send first invoice to company X	54	
Remove non-relevant options from electrical schemes	4	
Print electrical schemes and put them in maps	107	
Export electrical schemes to the website of the supplier	13	
Order materials	54	
Export invoices to AGP	54	
Book in products in AGP		-
Put materials in the right project box		-
Total times	290	

Table 3.2:1; The activity times of the preparation of the production process.

Production electrical cabinets

There are in total three electrical cabinets that have to be produced in this sub-process and the differences between these cabinets are quite big sometimes. Therefore the time of each activity is estimated per cabinet. When the column of the cabinet is empty, it means that the activity is not done separately per electrical cabinet, so for example for the Proneta-test the cabinets are all three tested simultaneously. All the activity times for this sub-process can be seen in below in Table 3.2:2.

Cabinet	Process	Time estimations (hours)	
		Production supervisor	Hardware engineer
SK100	Search through the materials	54	
SK100	Sticker materials	27	
SK100	Measure + draw on the mounting plate	215	
SK100	Drill holes, etc.	81	
SK100	Attach gutters + DIN-rails	20	
SK100	Place components	27	
SK100	Connect the cables to the components	859	
SK100	Place mounting plate	13	
SK100	Measure + draw on the door	54	
SK100	Die punch the door	54	
SK100	Place buttons in door and connect cables to the door/buttons	54	
SK100	Measure + draw on the gland plate	4	
SK100	Die punch the gland plate	18	
SK100	Mount the gland plate	54	
SK100	Peep the cabinet through	429	
SK100	Rewire the cabinet	215	
SK250	Search through the materials	54	
SK250	Sticker materials	13	
SK250	Measure + draw on the mounting plate	54	
SK250	Drill holes, etc.	54	
SK250	Attach gutters + DIN-rails	20	
SK250	Place components	27	
SK250	Connect cables to the components	54	
SK250	Place mounting plate	13	
SK250	Measure + draw on the door	-	
SK250	Die punch the door	-	
SK250	Place buttons in door and connect cables to the door/buttons	13	
SK250	Measure + draw on the gland plate	13	
SK250	Die punch the gland plate	20	
SK250	Mount the gland plate	54	
SK250	Peep the cabinet through	54	
SK250	Rewire the cabinet	27	
SK200	Search through the materials	107	
SK200	Sticker materials	4	
SK200	Measure + draw on the mounting plate	107	
SK200	Drill holes, etc.	81	
SK200	Attach gutters + DIN-rails	27	
SK200	Place components	54	
SK200	Connect cables to the components	242	
SK200	Place mounting plate	13	
SK200	Measure + draw on the door	13	
SK200	Die punch the door	13	
SK200	Placing buttons in door and connect cables to the door and buttons	13	
SK200	Measure + draw on the gland plate	13	
SK200	Die punch the gland plate	40	

SK200	Mount the gland plate	27	
SK200	Peep the cabinet through	161	
SK200	Rewire the cabinet	54	
	Test cabinets with Proneta	429	
	Adjust wiring, etc.	4	
	Aftercare	429	
	Order materials for assembly onsite		107
	Total times	4,610	

Table 3.2:2; The activity times of the production of the electrical cabinets.

Preparation cabling operating cabin

Just like for the sub-process of producing the electrical cabinets the activities are subdivided per electrical cabinet or per DESK. Below the time per activity is given in Table 3.2:3.

Cabinet	Process	Time estimations (hours)
		Production supervisor
SK300	Search through the materials	54
SK300	Sticker materials	27
SK300	Measure + draw on the mounting plate	215
SK300	Drill holes, etc.	134
SK300	Attach gutters + DIN-rails	134
SK300	Place components	40
SK300	Connect the cables to the components	215
SK300	Peep the cabinet through	161
SK300	Rewire the cabinet	54
DESK300	Search through the materials	107
DESK300	Sticker materials	27
DESK300	Lay down the setup of the DESK	81
DESK300	Connect the cables to the components	161
DESK300	Bundle the cables	81
DESK300	Peep the DESK through	67
DESK300	Rewire the DESK	54
DESK400	Search through the materials	161
DESK400	Sticker materials	54
DESK400	Lay down the setup of the DESK	81
DESK400	Connect the cables to the components	268
DESK400	Bundle the cables	54
DESK400	Peep the DESK through	81
DESK400	Rewire the DESK	54
	Total times	2361

Table 3.2:3; The activity times of preparing the cabling of the operating cabin.

Cabling operating cabin

The activities for the sub-process of cabling the operating cabin are subdivided by the electrical cabinets or DESKs that need to be cabled. In addition, the Profinet cable is separately mentioned, because that cable takes rather a lot of time. Below in Table 3.2:4 I have written down the time estimates of each activity in this sub-process.

Process	Time estimations (hours)	
	Production supervisor	Hardware engineer
Install SK300	13	

Build-in DESKs	107	
Connect the SK300	644	
Connect the DESK300	107	
Connect the DESK400	107	
Pull profinet cable	81	
Test operating cabin with Proneta	242	
Resolve problems	107	
Aftercare	429	
Adjust electrical schemes		27
Total times	1868	

Table 3.2:4; The activity times of cabling the operating cabin.

Preparing cabling at assembly onsite

The times that each activity takes at the assembly onsite are somewhat harder to estimate. The involvement of multiple external parties at the production location, the varying number of employees of Powerspex available at the assembly onsite and the rather time consuming processes are amongst others factors that caused the rather broad estimates. The broad estimates for the sub-process of preparing the cabling at the assembly onsite can however be seen below in Table 3.2:5.

Process	Time estimations (hours)
	Onsite supervisor
Rebuild the lamp	215
Pull and bundle all cables from and to the lamps	54
Connect the cables of the lamps	215
Drill holes and mount the lamps to the pontoon	429
Mount components in the dredger	215
Hang tie-wraps to pull cables through	644
Total times	1771

Table 3.2:5; The activity times of preparing the cabling at the assembly onsite.

Cabling within the hull of the vessel

The activities within this sub-process take rather long, which is why the sub-process of connecting the cables within the hull of the vessel is divided by the things that need to be connected within the hull of the vessel (like the electrical cabinets and the external components). The activity times within this sub-process are visualized below in Table 3.2:6.

Process	Time estimations (hours)
	Onsite supervisor
Pull the cables through the tie-wraps	134
Bundle the cables	564
Connect the components and cables that go out of the cabinets	188
Connect the SK100	1288
Connect the SK200	537
Connect the SK250	322
Connect the Caterpillar cabinets	215
Drill holes for the swivels in the battery boxes	54
Connect the battery cables	1288

Total times	4589

Table 3.2:6; The activity times of cabling within the hull of the vessel

Cabling between operating cabin and pontoon

The process of cabling between the operating cabin and the pontoon is rather short, with almost half of the time spent on administrative tasks. Nevertheless the number of hours spent on each activity can be seen below in Table 3.2:7.

Process	Time estimations (hours)	
	Supervisor onsite	Hardware engineer
Preparing the Roxtec	54	
Pull cables through the Roxtec	4	
Fasten the cables in the Roxtec	9	
Connect the cables	54	
Send second invoice to company X		54
Adjust electrical schemes		27
Total times	201	

Table 3.2:7; The activity times of cabling between the operating cabin and the pontoon.

Commissioning dredger

Despite the fact that there is already time spent in the process on testing, Powerspex will still have to perform the last test to guarantee the quality of the dredger. The hours spent on this process will be the final ones, before the standard dredger is entirely finished. The activity times can be seen below in Table 3.2:8.

Process	Time estimations (hours)	
	Field service manager	Hardware engineer
Perform visual check of cabinets and connected cables	27	
Connect the batteries	27	
Measure the values within the cabinets	107	
Download the software in the PLC and put in HMI-screens	161	
Test internal communication	107	
Test trip-signals of hydraulics	107	
Test trip-signals of auxiliary engine	107	
Test all hydraulics	483	
Test 400Volts system	215	
Test the main engine and dredge pump	161	
Make the connection to company X Digital	107	
Test the MB-connect	54	
Fill out SAT-report	81	
Send last invoice to company X		54
Adjust electrical schemes		27
Make end documentation		107
Total times	1932	

3.2.3 Comparison of estimates to the total time

Adding up the total times of all sub-processes leads to a total number of 17,550 hours that are spent in the production process according to these estimates. However, as earlier discussed in this thesis in

Section 1.4.1, the production of the hardware of a CSD500 in 2019 took 42,346 hours on average. Therefore the total number of hours spent in the process, according to the estimates, did not add up, which was however in line with my expectations because of various reasons.

First, whenever the employees are working on the hardware of a dredger they are doing all sorts of (small) activities in between, besides the main activities described within the answer to research question 1. The small activities are not processed in the process flow, as they are not planned and are done throughout the whole process. An example of one of these activities is managing the project. The employees of Powerspex do not take into account these (small) activities when I ask them for the time an activity takes.

Second, the many interns working on the company X projects, especially in the workplace in Hengelo, sometimes need help or guidance during their work. Then the intern will ask the production supervisor within the workplace to help him. The supervisor will then also register his hours on that project, which means that the number of hours registered on the project will be twice as much. However, these double hours are not taken into account when I ask for the time an activity takes. It would also be hard for an employee to guess the number of double hours on a project, because it depends on a lot of different factors like the competence of the interns, the number of interns on the project, etc.

Finally the travelling hours for the assembly onsite and the commissioning are not taken into account with the estimates, whilst these are in fact registered as working hours. The travelling hours are also hard to estimate as all employees working for Powerspex live in different locations and the employees working in City A differ per week. In addition, some employees of Powerspex do not have a fixed place where they live in The Netherlands, hence they are placed in different locations every week.

3.2.4 Conclusion

The estimates of the activities (17,550 hours) do not add up to the total number of hours spent within the production process of the dredger hardware (42,346 hours). The estimates differed quite much from the actual production time, because of multiple reasons. The travelling times, the double hours spent when helping interns and the small irregular activities in between the activities mentioned in the answer to research question 1. Although the estimates do not add up to the true total processing time, it does give an indication to how long each activity relatively takes within the process and how much effect the elimination or reduction of a specific non-value adding activity might have.

3.3 RQ3; Value adding activities within the process

The process and the processing times are now more clear, hence I will have to know the value adding parts of the process, so the next research question will have to be answered in this Section: 'What activities in the production process can be considered value adding for company X?'. To find out what parts of the production process of producing the dredger hardware are value adding I have held an interview with the company X purchasing manager. With this interview I will be able to view entire process from his, and not the least important, from company X's perspective. The value of company X will be discussed in Section 3.3.1. With the value of company X clear the non-value adding activities can be identified within Section 3.3.2 and the required non-value adding activities can also be identified in Section 3.3.3. In Section 3.3.4 the reasoning is given why the activities are considered (required) non-value adding and finally in Section 3.3.5 a conclusion will be given.

3.3.1 Company X and value adding activities

Company Y

Before the interview, the company X purchasing manager first explained some more about his company company X and the entire company Y with a slide show. Company X is a group that contains multiple companies all over the world. The thing that all these companies have in common is that they are doing something within the shipping business. Every company within company Y is either designing, building or maintaining ships. Company X as a company works with a specific business model, as they are working with the company X Standard. This means that every company within company Y has designed standard ships, which all companies are making to stock. Using a standard gives the companies of company Y multiple advantages. First, it will give them the opportunity to be more responsive to customer demand, as they are moving up a big part of their lead time. In addition, to moving up a big part of the lead time, the company X companies can produce cheaper as all the ships are standardised.

To get to know how the products and services of Powerspex are valued within the production of the Cutter Suction Dredgers I will first have to know some more about what The company Y and their customers again value in general. The first things that the company X Group values are the fundamentals of doing business. In the eyes of the purchasing manager these fundamentals are to deliver good quality products, to be good for the environment, to take good care of the work safety of employees and to be reliable as an employer towards both your employees and your customers, which includes doing business in a fair way. Besides these business fundamentals company X also values short lead times and low prices very much, as their business model with standardization attracts a lot of customers that value these two things as well. Company X wants to stay ahead of their competition regarding the lead times and the low prices, however company X also values innovation very much on both the area of engineering and process improvement.

Company X

Within the company Y there is company X. Company X is offering and building multiple Dredging solutions within the market. The three most important ones are the Cutter Suction Dredgers, the DOP Dredger pumps and the Trailer Suction Hopper Dredgers. The Cutter Suction Dredgers are provided with the hard- and software of Powerspex, hence the focus within this project is on the Cutter Suction Dredgers. There are 5 sorts of standardized Cutter Suction Dredgers produced within company X. Namely the CSD250, the CSD350, the CSD450, the CSD500 and the CSD650. These basic dredgers are then stocked in the canal, next to where company X is located. When a customer buys a dredger, the dredger is equipped with the desired options of this customer.

Creating value for company X

company X values very much the same things as the company Y, and company X values the same things again from their suppliers, which is amongst others Powerspex. Therefore company X also values the business fundamentals, which include a good product quality, short lead times, low product prices and continuous innovation from their suppliers. By continuously innovating company X also wants to improve the product quality, the lead times and the product prices of their dredgers. The purchasing manager explained more extensively how all these points are important to him.

Low product prices

First the purchasing manager of company X thinks that within the dredging market, a sale is not really made based on the customer goodwill but very much on price. Therefore he thinks that, as there are spent a lot of working hours within the production process of the dredger, the number of working hours should be reduced as much as possible to keep the cost prices of the dredgers low. With low product prices the competition can be beaten.

Short lead times
In addition, to low product prices, a short lead time is quite important for multiple reasons. First as already mentioned, the customers of company X value a short lead time. Second and third, because company X can be more responsive to their customers and keep on a lower inventory. Company X then will be able to keep on a low inventory, because company X offers 5 different standardized dredgers and with a long lead time there will have to be considered which products will be made to stock a long time before the demand comes in. As it is then not yet known which products will be sold, the wrong products might have been made to stock. With the wrong products on stock company X will have to have more dredgers on stock and with the wrong dredgers on stock company X has invested money in a dredger for which no customer is willing to pay (yet). If company X does not have a customer that is willing to buy a produced dredger, the cashflow of company X will be reduced. When the dredger would have been sold company X could use the money to build another dredger. A large stock quantity is considered a problem as a lot of inventory imposes a high financial risk for the enterprise. Hence to not increase the lead times the suppliers of company X will have to live up to their delivery agreements and the suppliers will deliver their products on-time.

Innovation
Finally company X wants to innovate a lot, because by innovation on multiple areas they can increase their value and decrease the dredger price for their customers, which is why they invest a great deal in research & development. During the interview the purchasing manager of company X gave a couple of examples for Powerspex to innovate and reduce the lead times and the costs. However, I have not given all examples within this thesis.

Conclusion
From this interview it can be concluded that company X mainly values the fact that suppliers satisfy their business fundamentals. This means that Powerspex will have to: deliver good quality products, be good to its own employees, be good to the environment, etc. Then company X also really values it if Powerspex can deliver their products on time and can shorten the lead times for their products. Besides on-time delivery and short lead times of the products, company X expects relatively good prices compared to the market and initiative to develop innovations on multiple areas. Finally, from the interview it can be concluded that company X would like to see improvements within the process, that might decrease the lead times and reduce the number of working hours within the production process, as long as these do not come too much at the costs of the product or service quality.

3.3.2 Non-value adding activities
Now it is known what company X considers value adding, hence the non-value adding activities can be distinguished from the process. Using the answers to research questions 1, 2 and 3, the literature research and my own experience within the process, I have found the next non-value adding activities:

- Walking up and down the dredger every time for needed tools or materials.
- Walking back and forth in the workplace for required materials and tools.
- Walking back and forth within the dredger when pulling, connecting and bundling the cables.
- Bundling the cables perfectly neat within the dredger and in the workplace in Hengelo.
- Searching the materials on the pallet of the dredger and searching for the lost materials.
- Measuring and drawing for drilling holes or die-punching.
- Fastening the tie-wraps to the cable ladders.
- Peeping through the cabinets, plate and the DESKs.

- Reconnecting the cables or resolving other faults after testing with either peeping through or Proneta.
- Testing the cabinets and operating cabin with Proneta.
- Adjust changes in electrical schemes.
- Rebuilding the LED-lights.
- Creating a project number at the invoicing department.
- Exporting the invoices from the supplier website to AGP.
- Aftercare of the cabinets and operating cabin.

The reason why all of these activities are considered (required) non-value adding will be given below in Section 3.3.4.

3.3.3 Required non-value adding activities

All of the non-value adding activities can be connected to one of the 7 original wastes of Lean, which are described in Section 2.3 of this thesis. In the Section 4.1 all of the non-value adding activities that I have found will then also be linked to one of the original 7 wastes of Lean, except for the required non-value adding activities. From the theory described in Section 2.6 of this thesis it can be deduced that a required non-value adding activity is an activity that does not add value to the customer, however is required under the current circumstances. Hence the next non-value adding activities are considered required:

- Exporting the invoices from the supplier website to AGP.
- Creating a project number at the invoicing department.

3.3.4 Why is it a (required) non-value adding activity?

The reason why the activities are either non-value adding or non-value adding, but required can be read below in Table 3.3:1.

#	Non-value adding process	Required?	Why is it a (required) non-value adding activity?
1	Walking up and down the dredger every time for needed tools or materials	No	Walking up and down does not add value to the product
2	Walking back and forth in the workplace for required materials and tools	No	Walking back and forth does not add value to the product
3	Walking back and forth within the dredger when pulling, connecting and bundling the cables	No	Walking back and forth does not add value to the product
4	Bundling the cables perfectly neat within the dredger and in the workplace in Hengelo	No	Overperforming the activity, as company X does not necessarily add the value to it to that extent, because it does not really affect the product quality
5	Searching the materials on the pallet of the dredger and searching for the lost materials	No	By just searching the materials, the product is not transformed in any

			way, hence it does not add value to the product
6	Measuring and drawing for drilling holes or die-punching	No	When the mounting plates, doors of the electrical cabinets and the gland plates are measured and drawn on, it does not add value to the product, as it is not transformed, hence it does not add value to the product
7	Fastening the tie-wraps to the cable ladders	No	When the tie-wraps are mounted to the cable ladders, it does not add any value to the product, as company X is actually paying Powerspex to pull and connect the cables at the assembly onsite
8	Peeping through the cabinets, plate and the DESKs	No	Inspection is considered a waste from the lean perspective, as it does not add anything to the fit, form or functionality of the product
9	Reconnecting the cables or resolving other faults after testing with either peeping through or Proneta	No	Everything that is not done the first time right, is considered a waste from the lean perspective
10	Testing the cabinets and operating cabin with Proneta	No	Inspection is considered a waste from the lean perspective, as it does not add value to the transformation of the product
11	Adjust changes in electrical schemes	No	Everything that is not done the first time right, is considered a waste from the lean perspective
12	Rebuilding the LED-lights	No	Everything that is not done the first time right, is considered a waste from the lean perspective
13	Aftercare of the cabinets and operating cabin	No	Parts of the aftercare are required for the ISO-standards which add value for company X, as it adds to the product quality. However, sub-processes of this activity can either be eliminated or kept to a

			minimum. As scanning the documents and sending pictures from the mobile phone to the email and uploading it to the server is considered a non-value adding activity
14	Exporting the invoices form the supplier website to AGP	Yes	This part does not add value for company X, but is purely necessary so that the daily administration can be done
15	Creating a project number at the invoicing department	Yes	This part does not add value for company X, but is purely necessary so that the daily administration can be done

Table 3.3:1; All non-value adding activities (but required) with the reason why it is (required) non-value adding.

3.3.5 Conclusion

Company X would like to reduce the number of working hours spent on a dredger, as long as this does not come at the costs of the quality of the dredger. In addition, company X would like to see innovations in both the production process, and the quality of the dredger with out-of-the-box solutions. Within the production process there have been found 15 non-value adding activities of which 2 are required non-value adding activities.

3.4 Conclusion

The process of company X can be subdivided into 8 subprocesses, which all contain a lot of activities again. According to the estimates of the employees all the activities within the process of producing hardware for a CSD500 take about 17,550 hours, whilst the average number of hours spent on a CSD500 in 2019 was about 42,346 hours. Multiple reasons might explain the differences between the estimates and the average number of hours spent in 2019. Traveling times are not considered by me and small (irregular) activities during working time and double hours registered for guiding interns might not be considered by both me and the employees within their estimates. Although I have found 15 non-value adding activities (of which 2 are required), there might be more non-value adding activities that I have not encountered yet during the process. With the 15 non-value adding activities that I have currently found I can however, continue with finding the (root) causes, to eventually find solutions to either eliminate the activities from the process or to reduce the number of hours spent on the activities.

4 Wastes and causes

In this chapter the lean wastes that have been identified will be discussed first in Section 4.1. For this the lean wastes found in Section 2.3 will be linked to the non-value adding activities found within the process. Next the causes of the non-value adding activities will be given in Section 4.2., so the root causes can be found and solutions can be thought of.

4.1 RQ4; Identified wastes within the current production process

In the next Section the research question: 'What lean wastes can be linked to the non-value adding activities found within the current 'company X process' within Powerspex?' will be answered. To find the lean wastes a literature research has been performed that can be read in the theoretical framework under Section 2.3. I will discuss how I have encountered wastes of motion, overprocessing and defects and errors within the process in respectively Section 4.1.1, Section 4.1.2 and Section 4.1.3. Next all non-value adding activities have been listed and linked to one of the three lean wastes in Section 4.1.4, before a conclusion is written in Section 4.1.5.

4.1.1 Waste of motion

The first waste that I have noticed within the process is the waste of motion. The waste occurred within both the workplace in Hengelo a lot and at the assembly onsite in City A. Wastes of motion are all activities that involve unnecessary movement in any way for the employees. A non-value adding activity, described in Section 3.3.4, that can be ascribed to a waste of motion is for example walking up and down the dredger for tools or materials. Walking up and down (for materials) is a movement that is not needed to get the hardware of the dredger finished. When the materials are for example on hand for the employee already, the process of walking up and down can be eliminated. The other non-value adding activities that can be ascribed to a waste of motion are listed below in Table 4.1:1.

4.1.2 Overprocessing

The next waste that I have identified within the production process is overprocessing. When there is more time spent on an activity then is required by the customer or when unnecessary steps reveal in the process it is considered overprocessing. Both spending more time than needed on an activity and unnecessary steps in the process have been identified in the process. The cables that are bundled at the assembly onsite takes up quite some time, at least more than required according to the value of company X. For example when the cables are not bundled tight enough some employees are cutting all the tie-wraps loose and start over with bundling all the cables again, even though these tighter bundles do not add any extra value to company X. In addition, the entire process of producing dredger hardware is also rather long and therefore complex, which leads to some unnecessary steps within the production process. For example when the employees of Powerspex in the workplace in Hengelo have to do a lot of processes before they can actually start with wiring the electrical cabinet. One of the processes that the employees have to do before wiring and is considered an unnecessary step is searching for materials. All non-value adding activities that can be linked to the lean waste of overprocessing are shown below in Table 4.1:1.

4.1.3 Defects and errors

The last lean waste that I have identified within the process is the one of defects and errors. Defects and errors often lead to rework and testing, which are not activities that are done the first time right, hence considered non-value adding. When the cables are connected there is often something going wrong with connecting them. The cables might be connected to the wrong component for example. As the cables can be wrongly connected rather easily there is quite some time spent on rewiring the cabinets in the workplace in Hengelo after peeping them through for example. Besides rewiring there are also a few other non-value adding activities that can be associated with the lean waste of defects and errors, which can all be seen in Table 4.1:1.

4.1.4 Non-value adding activities and the lean waste

All non-value adding activities within the current production process have been listed in Table 4.1:1 below together with the lean waste to which it can be associated. The non-value adding activity of searching the materials can be linked to two lean wastes. First it is linked to overprocessing, because it is an unnecessary step, as the search work would not be necessarily needed in the process at all (it does not add value to the product). Second, employees can sometimes not find the materials that they are searching for on the project pallet, which leads to the employees searching for the materials throughout the workplace in Hengelo. Therefore the searching for materials is also considered a waste of motion.

#	Non-value adding process	Waste
1	Walking up and down the dredger every time for needed tools or materials	Waste of motion
2	Walking back and forth in the workplace for required materials and tools	Waste of motion
3	Walking back and forth within the dredger when pulling, connecting and bundling the cables	Waste of motion
4	Bundling the cables perfectly neat within the dredger and in the workplace in Hengelo	Overprocessing
5	Searching the materials on the pallet of the dredger and searching for the lost materials	Overprocessing/ waste of motion
6	Measuring and drawing for drilling holes or die-punching	Overprocessing
7	Fastening the tie-wraps to the cable ladders	Overprocessing
8	Peeping through the cabinets, plate and the DESKs	Defects and errors
9	Reconnecting the cables or resolving other faults after testing with either peeping through or Proneta	Defects and errors
10	Testing the cabinets and operating cabin with Proneta	Defects and errors
11	Adjust changes in electrical schemes	Defects and errors
12	Rebuilding the LED-lights	Overprocessing
13	Aftercare of the cabinets and operating cabin	Overprocessing

Table 4.1:1; All non-value adding activities linked to the lean waste.

4.1.5 Conclusion

In total there are three sorts of lean waste identified. Waste of motion is the first lean waste that I have identified within the process. Next, overprocessing is noticed in the process in two ways. First, the employees of Powerspex sometimes desire a quality that is higher than company X as customer is asking. Second, I have noticed that the entire process is rather long and complex and that there are a lot of unnecessary activities done within the process. Powerspex then assumes these activities to be needed to perform the main activity in the process, namely connecting the wires. Finally, it is noticed that a lot non-value adding activities in the process can be linked to the lean waste of overprocessing.

4.2 RQ5; Root causes

In this section the following question will have to be answered: 'What are the (root) causes of the non-value adding activities within the current production process of Powerspex?'. I will first explain a bit more about how I have come to the root causes in Section 4.2.1. Then I will describe the causes of the non-value adding activities per lean waste encountered in the current production process in Sections 4.2.2, 4.2.3 and 4.2.4. In Section 4.2.5 I have visually represented all of the causes in a problem cluster. Finally, I have listed the root causes in Section 4.2.6, before I have concluded this Section 4.2 in Section 4.2.7.

4.2.1 Methodology

By using my experience within the production process and having asked questions to the employees of Powerspex, if needed, I have first described most of the causes for the non-value adding activities. As all activities are already categorized per lean waste it is easy to use these lean wastes to come to the root causes of the non-value adding activities. Therefore I have explained the causes for all the activities below per lean waste. The non-value adding activities that can be ascribed to the defects and errors, described in Section 4.1.4, have multiple causes. The defects and errors are all somewhat connected, for example if mistakes are made during the process, more testing will be needed, as well as more rework. Adjusting the electrical schemes is also considered rework.

4.2.2 Defects and errors

When employees are testing the electrical cabinets and the operating cabin within the workplace in Hengelo they are all testing it by hand. Although the Proneta test is done partly with software, it will still have to be controlled by an employee. When the tests are performed by employees it is prone to human errors. In addition, a lot of mistakes are made already when the cabinets and the operating cabins are cabled. The reason that many mistakes are made is that there is a lack of standardization of the process and the people working in the process. Many interns are working on the projects, hence many different employees are working on it. Also the cabinets do not always have a fixed layout, which leads to the fact that the cabinets need to be cabled differently. Finally, a lot of hardware is tested double in the process, to double check if everything is well-connected.

4.2.3 Overprocessing

First bundling the cables takes quite long, as it is often overdone by the employees of Powerspex. The employees are overdoing it, because the cables are bundled in full-sight, hence it has to look neat. However, also because the cables have to be bundled with tie-wraps on a vertical placed cable ladder, which is a rather unpractical way to bundle the cables neatly. The non-value adding activity of fastening the tie-wraps to the cable ladders is also connected to the fact that the cables have to be bundled on the vertically placed cable ladder with tie-wraps.

The time that the employees spend on searching the materials on the pallet of the dredger is due to the fact that all materials are mixed upon one pallet. When the materials are searched together the plates and doors are measured and drawn so they can processed by die-punching or drilling. The activities of measuring and drawing are caused by the fact that the layout switches every time, hence the activities cannot be automated as easily. Moreover, the materials are not always available to make the activities quicker, for example the moulds to easily measure and draw the right patterns on the plate or door are not always present. The aftercare demands quite some time, due to some unnecessary steps. The unnecessary steps are caused, because there is no device available that is both connected to the Powerspex server and can make pictures. Furthermore, the scans of the maps with the electrical schemes are made by hand, which is rather time consuming. Finally the LED-lights have to be rebuild as the LED-lights currently used are quite unpractical with the long wire installed on the wrong side of the LED-light.

4.2.4 Waste of motion

The employees of Powerspex at the assembly onsite are often walking up and down the dredger as they need a lot of materials for their activities. The employees often do not know which materials they need and how many pieces they need before they start the activity. Within the dredger the employees also have to walk back and forth a lot when pulling the cables. Walking back and forth in the dredger is quite time consuming, because there is only little space in the dredger. The small spaces are because of the fact that there are a lot of persons working within the dredger simultaneously and because there are no easy pathways in the dredger, as the employees need to walk over pipes. Finally, the employees in the workplace in Hengelo sometimes have to search for the materials of the dredger outside of the project pallet, because they do not always know if the materials have come in or not. First, the employees have to search, because they cannot see which materials are booked in. Second, the materials are sometimes not properly booked in, as booking in materials is quite unpractical.

4.2.5 Problem cluster

With all the causes of the non-value adding explained I have made a problem cluster. Normally, according to Heerkens, Van Winden & Tjooitink (2017), a problem cluster is an overview of an action problem and the core problems causing the action problem. However, in this research I already have a core problem and I will have to find the root causes of this core problem. Therefore, the problem cluster will be used to find the root causes for the core problem.

With the problem cluster I can easily visualize all the root causes of the core problem within this research. Within the problem cluster of this research, that can be seen below in Figure 4.2:1, the blue square is the core problem and the root causes of this action problem are the red and green squares. The green squares are, opposed to the red squares, solvable. The red squares namely have either external causes (in the case of the ones most left), fall outside of the scope of this research (the bottom one) or cannot be eliminated from the process due to other reasons (the upper one). For the processes it would be hard to reduce the (number of) needed materials. To make the problem cluster more clear, I have indicated the non-value adding activities in the problem cluster with a number from Table 4.2:1 below.

#	**Non-value adding process**
1	Walking up and down the dredger every time for needed tools or materials
2	Walking back and forth in the workplace for required materials and tools
3	Walking back and forth within the dredger when pulling, connecting and bundling the cables
4	Bundling the cables perfectly neat within the dredger and in the workplace in Hengelo
5	Searching the materials on the pallet of the dredger and searching for the lost materials
6	Measuring and drawing for drilling holes or die-punching
7	Fastening the tie-wraps to the cable ladders
8	Peeping through the cabinets, plate and the DESKs
9	Reconnecting the cables or resolving other faults after testing with either peeping through or Proneta
10	Testing the cabinets and operating cabin with Proneta
11	Adjust changes in electrical schemes
12	Rebuilding the LED-lights
13	Aftercare of the cabinets and operating cabin

Table 4.22:1; All non-value adding activities with their associated numbers.

The non-value adding activities of the defects and errors are taken together in the problem cluster, because these have a lot to do with each other and have a lot of the same root causes. Moreover, non-value adding activity number 5 is given 2 times, because this non-value adding activity has two dimensions. The searching on the project pallet for materials of employees is seen as overprocessing (an extra process that is not necessary). However, if the materials are not present within the project pallet then the employees are searching around in the workplace in Hengelo, which is seen wastes of motion. Finally, the non-value adding activities number 4 and 7 are taken into one, because their (root) causes are similar.

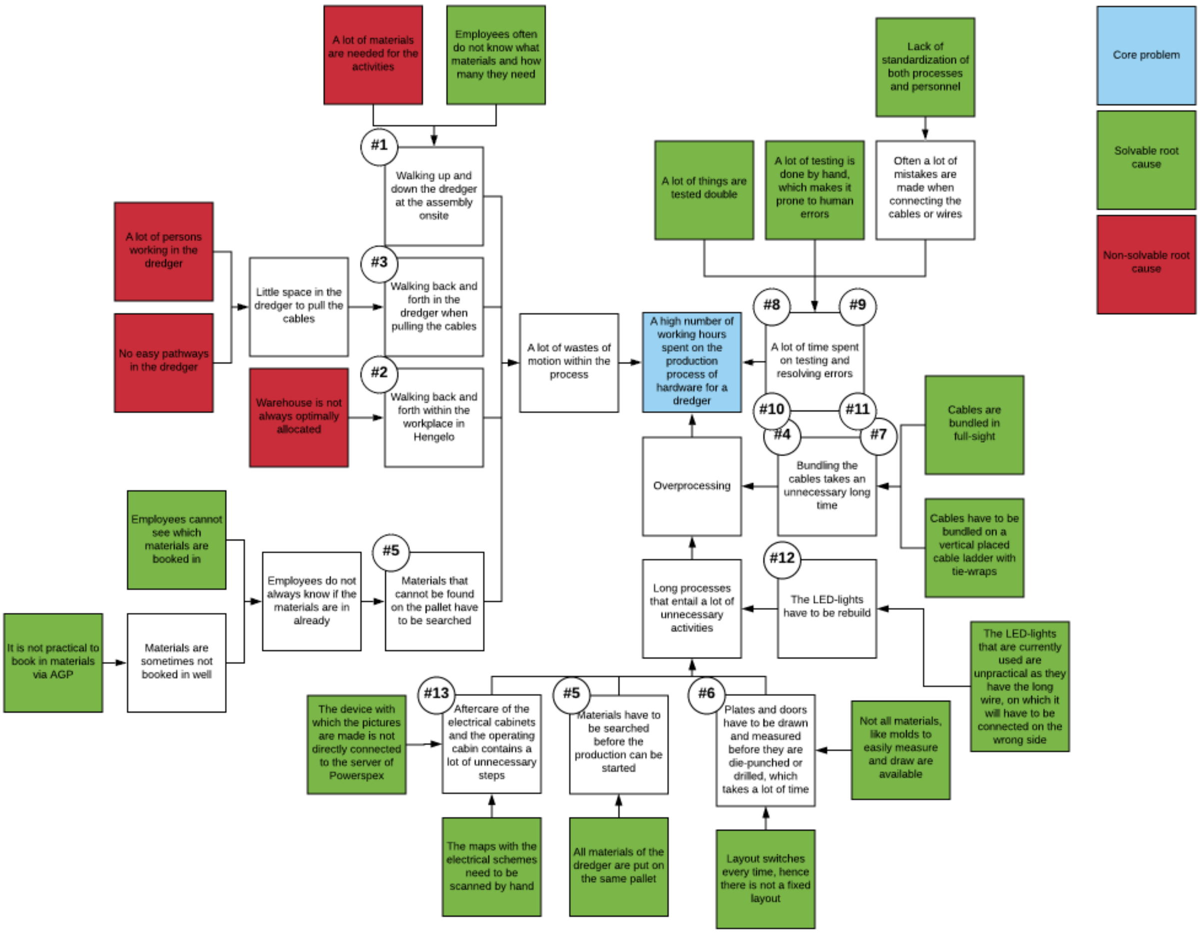

Figure 4.2:1; The problem cluster. The blue square in the middle represents the core problem, the squares that are not filled are causing the core problem and the green and red squares are the root causes of the core problem.

4.2.6 The root causes

The high number of working hours spent on producing the hardware for a dredger is caused by the following solvable root causes, that I have found. Behind the causes I have put the numbers of the non-value adding activities that they are causing:

- The employees do often not know which materials they need and how many exactly before they start the activity (#1).
- The employees cannot (easily) see which materials are booked in (#5).
- Booking in the materials via AGP is quite unpractical (#5).

- There is not a device available in the workplace that is both connected to the server of Powerspex and can make pictures (#13).
- The maps (with the electrical schemes) are scanned by hand (#13).
- All materials of the dredger are put on the same pallet (#5).
- There is not a fixed layout of the electrical cabinets (#6).
- Not all materials are available to either automate the activity of drawing and measuring or to make the activity of drawing and measuring less time consuming (#6).
- The current LED-lights that are used are unpractical (#12).
- The cables have to be placed with tie-wraps on a vertical placed cable ladder (#4 and #7).
- The cables are bundled in full-sight (#4 and #7).
- There is a lack of standardization regarding the process and the people working on the process (#8, #9, #10, and #11).
- A lot of testing the cables is done by hand, which makes it prone to human errors (#8, #9, #10, and #11).
- A lot of hardware is double tested (#8, #9, #10, and #11).

4.2.7 Conclusion

I have found 18 root causes that are causing the high number of working hours within the production process of Powerspex. 14 Out of the 18 root causes are considered to be solvable. In the next chapter, Chapter 5, solutions can be generated to solve these 14 root causes.

5 Solutions

The root causes are clear, which means the next research question can be answered: 'How can the non-value adding activities be eliminated or the number of hours spent on it be reduced as much as possible?'. To answer this question alternative solutions will have to be searched for. To find alternative solutions I have first searched for possible solutions in multiple ways, described Section 5.1 below. After the possible solutions are found, these solutions are proposed to the employees of Powerspex, that are the most important stakeholders in the process. The results of the group session with the stakeholders will be taken along in Section 5.2 where the solutions will be evaluated by means of the number of saved hours, the investment costs and the other (dis)advantages and where possible additional solutions will be discussed that have presented itself during the group discussion.

5.1 RQ6a; Alternative solutions

In this section the following sub question will be answered: 'What are possible solutions to either eliminate or reduce the time spent on non-value adding activities?'. In Section 5.1.1 I will first describe a bit more of the methodology that I will use for finding the solutions, before I will discuss all the alternative solutions that I have found in Section 5.1.2 to solve the root causes.

5.1.1 Methodology

To find solutions for all the root causes that I have found within the answer to research question 6a, I have tried to come up with solutions to some of the problems via multiple ways:

- I have searched for possible solutions on the internet.
- I have had one-to-one discussions with multiple stakeholders within the process (all stakeholders are also employees of Powerspex).
- I have used logical reasoning.

The choice to find alternative solutions before the group session was made, because then I could propose some ideas already and start the discussion during the session. If all the solutions to the root causes had to be thought of during the group session there is only a small time frame during which solutions might be thought of. In addition, to a small time frame it might be easier to get a discussion started during the group session when ideas can be proposed to the group already.

For most of the root causes there has been thought of solutions that can solve both the root causes, hence 1 solution that solves 2 problems. The process below describes how I have come to the solutions to solve the root causes, and reduce the time spent on non-value adding activities.

5.1.2 Alternative solutions to the root causes

Root causes: the cables have to be placed with tie-wraps on a vertical placed cable ladder & the cables are bundled in full-sight.

As bundling the cables within the dredger at the assembly onsite takes up a lot of time, by tie-wrapping the cables on the cable ladders, I have first searched for solutions on the internet to see if there might be different solutions to use instead of tie-wraps. However, this search did not result in any relevant alternatives.

During an interview that I had with the field service manager, he told me that back in the days they used cable harnesses to bundle the cables. Cable harnesses are assemblies of electrical cables that transmit signals or electrical power. The cable harness can be made of different materials, like rubber, electrical tape or extruded strings weaved together. An example of a cable harness is given below in Figure 5.1:1, in this example the harnesses are the blue hoses through which the cables are pulled. The cable harnesses could be an alternative that might help to lessen the number of working hours when bundling the cables at the assembly onsite. When cable harnesses are used, a bundle of cables could go through the cable harness, and most of the work could then be done upfront when all the cables are pulled and bundled outside of the dredger already. Then the cable harnesses only need to be carried into the dredger itself.

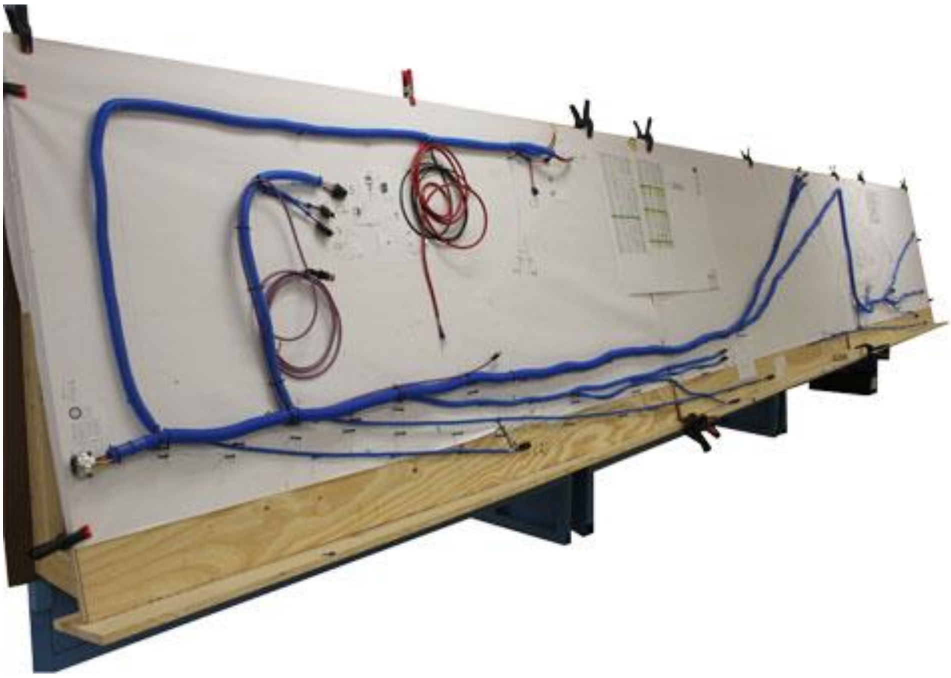

Figure 5.1:1; An example of a cable harness placed around the cable bundles. The blue object should represent a cable harness

Another option that has been thought of during the interview with the field service manager was to use pipes within the dredger. When pipes would be installed within the dredger the cables could be pulled through these pipes, which would make the fact that the employees at the assembly onsite do not have to tie-wrap the cables to the cable ladder anymore.

The last solution that has been thought of was to use cable gutters within the dredger. The idea of using cable gutters was thought of in a discussion with the onsite supervisor of Powerspex in City A. Cable gutters are inflexible solutions to hold the cables, as they are very static. An example of a regular industrial cable gutter is given in Figure 5.1:2. The idea was to place cable gutters with the opening to the side in the dredger with a lid and a hook. When using a cable gutter the cables do not need to be bundled as the cables are simply pulled through the gutter and placed behind the hook that will then be placed within the cable gutter. The hook will then keep the cables in place and will enable the employees at the assembly onsite to easily pull the cables behind it. The cover can be placed over the opening of the cable gutter, so that it looks neatly finished and the employees do not need to worry about how the cables are bundled.

Figure 5.1:2; An example of a regular industrial cable gutter.

Root cause: all materials of the dredger are put on the same pallet.
Next I have thought about how to solve the fact that all the raw materials of a project are being thrown on the project pallet. I have thought of the idea to subdivide the dredger in multiple compartments by using (wooden) crossbars. With the use of a subdivided pallet, all the materials of one cabinet or DESK can be separated and grabbed by the production employee. The production employee then does not need to search for the materials every time.

Root causes: there is not a device available in the workplace that is both connected to the server of Powerspex and can make pictures and the maps (with the electrical schemes) are scanned by hand.
To solve the problem of the fact that a lot tasks need to be done before both the electrical cabinets and the operating cabin will be picked up, I have had a discussion with the service manager of Powerspex. The service manager had an idea to have an iPad in the workplace in Hengelo, which is directly connected to the server of Powerspex. When the aftercare is normally done the employees will have to make the pictures with their own phone send the pictures to the computer by email. The pictures will then have to be uploaded to the server of Powerspex from the mail. When an iPad will be directly connected to the server of Powerspex, the pictures can be easily made and directly put into the right map within the server of Powerspex. In addition, the iPad can easily make pictures of the pages in the map or the maps can be uploaded to the iPad, where the electrical schemes can also be automatically adjusted. The maps can then easily be uploaded to the server of Powerspex.

Root cause: The employees do often not know which materials they need and how many exactly before they start the activity.
When speaking with the supervisor at the assembly onsite in City A he told me that he already had an idea to diminish the number of hours spent on walking up and down the dredger every time for tools

and materials. Namely the supervisor at the assembly onsite had already purchased a few boxes in which the materials and tools that are needed could be stored, however he did not have a lot of boxes yet. When the employees at the assembly onsite then need to connect the battery cables they can take the material box, so that the employees do not need to walk up and down the dredger every time. Afterwards this idea has been discussed also with the service manager of Powerspex and he told me that it would be good to fill the boxes in the workplace in Hengelo, where all the materials are coming in. When the boxes are filled in the workplace in Hengelo the employees will have to have a material list that is needed for each activity, so the employees at the assembly onsite will have all the needed materials and the right number of materials. There are already material lists available (which are often not used at the assembly onsite), hence these lists should only be divided per activity.

Root causes: a lot of testing the cables is done by hand, which makes it prone to human errors and a lot of hardware is double tested.
I have been discussing the problem of testing the electrical cabinets and the operating cabin with the service manager of Powerspex. The service manager had an idea to automatically test the cabinets by using software that is able to test the electrical cabinet part for part, so that the Proneta test and the peeping through can be done in one test. However, to be able to do the test with 2 in 1 there will first have to be a software program developed.

Root causes: there is a lack of standardization regarding the process and the people working on the process, there is not a fixed layout of the electrical cabinets and not all materials are available to either automate the activity of drawing and measuring or to make the activity of drawing and measuring less time consuming.
A lack of standardization both causes a lot of rework and the fact that the doors, mounting plates and the gland plates of the electrical cabinets have to be measured and drawn every time. To standardize the process for the sake of both preventing rework and measuring and drawing the parts of the electrical cabinets every time, I have thought first to standardize the layouts of the electrical cabinets. By standardizing the layout of the electrical cabinets the employees within the workplace in Hengelo also have more standardization in connecting the cables to the components, which leads to less mistakes, hence less rework. Moreover, a standardized layout of the electrical cabinets also makes the fact that moulds can be made, which can be used to draw the (standard) layout on the mounting plates, the gland plates and the doors of the electrical cabinets. The idea of using moulds occurred to me, because the employees are already using the moulds for some electrical cabinets within the production in Hengelo. In addition, to using moulds the service manager of Powerspex came with an idea to outsource the entire process of drilling holes in the three parts of the electrical cabinets where the layout can be standardized. By outsourcing the process of drilling the holes, the activities of measuring and drawing can be fully eliminated from the process too.

Root cause: the current LED-lights that are used are unpractical.
The current LED-lights that are used are rather unpractical for use, as they need to be rebuild before they can be connected to the cable and hung up in the pontoon. The best and easiest way to solve this is to look on the market for possible other LED-lights that can also sustain high temperatures (at least 80 degrees Celcius).

Root causes: the employees cannot (easily) see which materials are booked in and booking in the materials via AGP is quite unpractical.
Currently the employees cannot easily see which materials of a project are booked in. For this I have thought to also use the iPad, so employees can quickly check online which materials are booked in.

However, a condition for this is that the iPad will have to have access to the ERP-system AGP. I have not been able to find a solution for the unpracticality of booking in the materials in AGP.

5.2 RQ6b; assessing the solutions.

Most alternative solutions have been found, hence the next research sub question can be answered: 'How much benefit can Powerspex get out of each solution, compared to the costs and other disadvantages that come with each solution?'. I have operationalized the benefit of each solution by estimating the number of hours saved with that particular solution. To answer this question I will discuss the solutions that I have found per non-value adding activity from Section 5.2.1 until Section 5.2.7 and the solutions that have presented itself during the group discussion. Respectively the next non-value adding activities are discussed: testing and rework, search work, aftercare, walking up and down the dredger, bundling the cables, measuring and drawing and rebuilding the LED-lights. Finally, in Section 5.2.8 this section will be concluded.

5.2.1 Testing and rework

There is no complete consensus yet on how the lots of testing and rework can be eliminated from the process. However, there are two things the interviewees are telling me. First that it might be possible to test most of the cabinets by only peeping through the power supplies, so the 24Volts-system and the 400Volts-system. When an electrical cabinet is now tested the parts that go to the PLC, which are called the in- and outputs, will also be tested. However, the in- and outputs will already be tested with Proneta, hence it is not necessary to peep through the in- and outputs. Second the employees would want to have the same people working on the job every time. By having the same people working on the projects, the peeping through could even be fully eliminated from the process. The interns could then maybe connect the power supplies and do the mechanical work, as these are both relatively simple jobs. However, having the same people on the job comes with some disadvantages, that will be discussed below after the header of (dis)advantages. Finally, I have come up with a solution together with the service manager of Powerspex in Section 5.1.2 to develop a software program to test the electrical cabinets and the operating cabin.

Number of saved hours

In total within the process there is a lot of time spent on testing and rework. Within the workplace there is already spent about 1610 hours to test the products and about 537 hours resolving errors (including adjusting the electrical schemes). After the group session it was clear that peeping through the electrical cabinets is mainly needed for the power supplies. A production employee within the workplace in Hengelo told me that peeping through the in- and outputs took him about a little more than 50% of the total time that he needs for peeping through a cabinet. So when implementing the solution of only peeping through the power supplies, about 50% of the time peeping through will be saved, which is a little more than 470 hours.

When the same people will be put on the process and no peeping through is needed, there will be saved about 939 hours. Also the number of hours spent on rework can be reduced, however the total number of hours that can be reduced this way cannot be easily estimated. Currently there is spent about 537 hours on rework during the process (including adjusting the electrical schemes).

Using a custom made software for testing the electrical cabinets and the operating cabin, the service manager of Powerspex expects to be able to do two tests in one. Therefore I would expect the testing time to go down about 50%. When currently there is spent about 1610 hours on testing the products, I would expect the time spent on testing to be decreased by about 805 hours. In addition, there will also be less time spent on the rework which is about 537 hours (including adjusting the electrical schemes). It is assumed that about 50% of the time of the rework is saved, which is 268 hours. In total this solution would save up to 1073 hours.

Investment costs
To leave out the activity of testing the in- and outputs no investments are needed and having the same people on the process, no (direct) investments are needed.

However, to develop a software program to test the electrical cabinets and the operating cabin I would hire an intern that might be able to write a testing program. Assuming the net costs of an intern are about €22,541 per month and the internship takes about 6 months, an investment would be needed of €135,246.

Other (dis)advantages
Only peeping through the power supply parts of the cabinets might lead to the fact that resolving errors with the Proneta test might take longer. It might take longer, because the employees then might need to search longer for what the mistake is. I do not think however that the time loss of resolving these errors will weigh up against the time savings that will be reached. By only testing the in- and outputs once there might also occur more mistakes later in the process, as more mistakes might not be noticed.

When the same people will be put on the process there are at least two disadvantages. First, the job for both the interns and the experienced employees of Powerspex will get more boring, as they have to focus on fewer activities. Second, when the peeping through is not done at all there might be faults made in connecting the wires to the components (even though the employees are very experienced, mistakes will always be made some time). Then when the power is connected during the Proneta test, a problem might occur, which can lead to the breakdown of parts. When parts breakdown the hardware of the dredger is not moving forward in the production, as there will have to be waited for spare part to be ordered.

Finally, when a software program is made to test the cabinets and the operating cabin at once it would have the advantage that there will have to be less time spent on rework in the process. In addition, the onsite supervisor and the field service manager will rest better, assured that the cabinets and the operating cabins are well-tested. Finally, Powerspex can better guarantee the quality of the products that they deliver as it is better tested, than when the products are tested by hand.

Conclusion
I would not recommend putting the same experienced people on the company X projects every time to leave the peeping through out of the process and to reduce the number of working hours spent on resolving errors. In my opinion the disadvantages are too high, especially the fact that the work for the regular employees and the interns will become more boring. Powerspex as a company highly values the well-being and the job satisfaction of its employees.

On the contrary I would recommend Powerspex to not peep through the PLC-parts, but to leave out this part of peeping through so it can be tested during the Proneta test. The disadvantages of not peeping through the PLC-parts do not weigh up against the number of saved hours that can be reached in my opinion.

Finally, although the option to not peep through the PLC-parts is recommended on the short-term I would work towards the solution of developing a software program to test the cabinets and the operating cabins. The software program does require quite an investment of about €135,248, nevertheless the extra number of saved hours and the multiple extra advantages that it has are considered to outweigh the investment costs in my opinion.

5.2.2 Search work

For the search work that is done before starting with an electrical cabinet or a DESK, the option to divide the pallet into multiple compartments by using crossbars was proposed. The idea of using crossbars was received quite good. However, there were a few remarks from the employees which should be taken into account here that will be discussed below under the paragraph of the (dis)advantages. In addition, I have thought about how the employees do not need to search for the materials anymore when they cannot be found in the project pallet. The option to use the iPad to see if the materials are booked in indeed via AGP will be used. The problem regarding the unpracticality of booking in materials in AGP I have not been able to find a solution.

Number of saved hours

During the group session a solution has been discussed, which was to order all materials per cabinet and to divide up the pallet in 4 parts. When the pallets are divided in four parts the employees do not have to search for all the materials before they can start with the production of an electrical cabinet. Taking into account the estimates of the production supervisor in research question 2 there is spent about 537 hours in total on searching for the materials. For a standard CSD500 there are 4 electrical cabinets and 2 DESKs however, the pallet will be subdivided into 4 parts instead of 6. With 6 parts on the pallet the spaces become too small. According to the production employee in the workplace in Hengelo the search time could be fully eliminated with the materials subdivided on the pallet. However, with 4 compartments and 6 cabinets and DESKs some materials will be placed together on the pallet. Therefore the production employee told me that when he has to search through the materials of 2 cabinets or DESKs it would save him up to 50% of the time. In total 537 hours are spent on searching through the materials. To reduce the most number of working hours, the cabinets with the fewest number of materials will have to be joined on the pallet. The materials of the SK100 and the SK250 are therefore together in the same compartment of the pallet and the materials of the SK200 and the SK300 are in the same compartment of the pallet. In total there will be saved an amount of 403 hours with this division.

The number of hours spent on searching for materials that cannot be found on the dredger by the employees are difficult to estimate. The activity is not taken into account with the estimates, because this activity does not happen on a regular basis. Sometimes parts are often booked in whilst they are not delivered a lot during a project, but how many times it happens and how long the search takes is not exactly known. I am assuming that it would 54 hours for two men to find the lost material. Assuming that 1 product per projects is gone missing I would guess that about 50% of the products can be found immediately with the iPad. Hence this solution would save about 54 hour.

Investment costs

Besides the hours spent on making the barriers to divide the pallet there are no investment costs involved. The hours spent on making the barriers are however negligible.

The iPad however does need an investment. Nevertheless another solution involves the purchase of an iPad already, which is the solution discussed in Section 5.2.3.

Other (dis)advantages

When this solution will be implemented it will have to be taken into account that the work will not be moved to the warehouse manager for example. Therefore there has been spoken with the warehouse manager about this matter. He thinks that it will not cost him a lot of extra time to sort all

the materials per cabinet, as he is handling all the materials that are coming in already piece by piece. The only difference for the warehouse manager is that he will have to sort it in the right bin or part of the pallet, and the time spent on this is negligible.
Also there will have to be considered how this idea can be put into practice. At the moment the pallets are often quite small compared to what goes on a project pallet. Therefore for the implementation of this solution the space in the inventory will have to be considered.

Conclusion
The solution of dividing the incoming materials per DESK and cabinet will be recommended to implement to Powerspex. With 403 hours saved, negligible investment costs and few disadvantages the solution seems more than appropriate to implement. The only side note is the amount of space available within the warehouse.

The solution to use the iPad to see if the materials are already booked in would save about 54 hours, whereas the iPad will probably be used for another solution already, hence no investment costs are needed. Therefore I would recommend this solution to Powerspex.

5.2.3 Aftercare
In order to reduce the time spent on making pictures and scanning the maps onto the drive, an iPad would help. This iPad will then have to be connected to the drive and the pictures and the scanned documents will then have to be uploaded to the server automatically. This way all the actions that are needed to upload all parts to the drive can be eliminated. With the use of an iPad not all pictures will have to be made with the phones of employees so they have to send them to their own email, download the pictures from there and then upload them onto the server of Powerspex. In addition, not all maps will have to be scanned onto the computer, as the maps can be seen and adjusted on the iPad.

Number of saved hours
The aftercare of the cabinets and the operating cabin takes quite long. The part of the aftercare that is non-value added is the part where the pictures are made and where the pictures and the maps with the electrical schemes are uploaded to the server. After I had discussed with the production supervisor in the workplace and the general production manager it has been estimated that there can be saved about 81 hours per dredger. The 81 hours is found by estimating an average time of 13.5 hours per electrical cabinet and DESK and then multiplying the 13.5 hours with the 6 cabinets that a CSD500 normally has.

Investment costs
To implement this solution, the management of Powerspex will have to purchase an iPad. Besides the iPad a protective cover is also needed, the employees namely indicated in the group session that they were afraid the iPad will break down too fast otherwise.
An iPad, including 2 year insurance will cost around: €30,485 (Apple Inc., 2020) and a protective cover will then cost around: €1,342 (Smartphonehoesjes.nl, 2020), which results in a total investment of €31,826.

Other (dis)advantages
An iPad connected to the server will make it easier for the employees of Powerspex to make the pictures. By making it easier for the employees, they are more tempted to really make the pictures. Also the iPad can help the employees to easily check the (old) electrical schemes or the (old) pictures of the electrical cabinets. The electrical schemes and pictures can help the employees to see how the cables should be connected and how a problem has been solved before.

Conclusion
Although the investment costs are quite high with €31,826 and it can save only about 81 working hours per dredger the iPad will be recommended. The solution with the iPad will be recommended, because of the additional advantages that it has for the employees, like the fact that the iPad can help the employees to easily check the old pictures of electrical cabinets.

5.2.4 Walking up and down the dredger

For the assembly onsite multiple solutions were considered during the group session to help eliminate non-value adding activities like walking up and down the dredgers. Walking up and down the dredgers is mainly caused by the fact that the employees do not have all the materials and tools that they need when working in the dredger. Therefore we, the onsite supervisor and I, have thought of making boxes with the materials and tools that are needed (the most) when performing a specific activity. Examples of activities for which boxes can be made are: connecting the cables to the external components within the dredger or connecting the battery cables within the dredger.

Number of saved hours
The onsite supervisor told me that on a regular working day it happens about 5 times that an employee has to walk up and down the dredger. One time walking up and down costs the employee about 3 hours and on average there are about 3 employees working within the assembly onsite. The 3 employees are busy with a dredger for about 4 weeks on average. In total about 805 hours are spent on walking up and down the dredger. The onsite supervisor told me that about half the times walking up and down the dredger could be prevented with the tool- and material boxes. So in total about 403 hours can be saved.

Investment costs
The management of Powerspex will have to buy boxes in which the materials and tools can be stored. A material box costs about €644 (HBM machines BV, 2020). Assuming that there are three extra material boxes needed, as there are three employees working in the assembly onsite on average, this comes down to a total investment of: €1932.

Other (dis)advantages
The material boxes will have to be filled by the employees in the workplace in Hengelo, which will involve additional working hours. However, normally the employees at the assembly onsite will also have to search for the materials, so this will only relocate the work and will not lead to extra hours.

Conclusion
With 403 working hours saved per dredger, an investment needed of about €1932 and almost no other disadvantages this solution is considered to be a suitable one. Therefore it will be recommended to implement this solution within the production process.

5.2.5 Bundling the cables

Then for the bundling of the cables, which costs quite a lot of time, I have been thinking of multiple solutions with the employees, both before and during the group session. The three most important ideas that have been discussed are: cable harnesses around the cable bundles (or plastic hoses), pipes installed in the dredger of about 3 to 4 meters long and cable gutters installed in the dredger. The number of saved hours for each solution are difficult to estimate, because for example with the pipes there will still have to be time spent on bundling the cable bundles between the pipe and the pulling of the cables might cost some extra time. In addition, the number of investment costs are also hard to estimate, as installing the pipes in the dredger will then have to be done by a supplier of company X. Therefore the estimation of the investment costs is only limited and the number of saved hours of each of these three solutions is not given in this thesis, due to time limits. However, I will elaborate more on these solutions in the implementation plan in Section 6.1.5 of this thesis. In the next paragraphs I will however elaborate more on the other (dis)advantages of all three the solutions.

Number of saved hours

In total about 644 hours are spent on fastening the tie-wraps to the cable ladders and there is spent about 564 hours on bundling the cables within the dredger. When using a cable harness the time that is spent on both processes should be reduced, as employees do not need to be busy a long time with bundling the cables anymore. With the other two solutions the possible number of saved hours should be more than with using a cable harness, as the cables do not need to be bundled as much. However, in practice it will have to show which option is considered the best.

Other (dis)advantages

<u>Cable harnesses or plastic hoses</u>

First, the cable harness or the hose is quite heavy as there will have to be a lot of thick cables in it, which makes it difficult to transport. For example when the employees will bundle the cables outside of the dredger and will then carry it in the dredger it is quite heavy to get it in the dredger. Next, the employees are often busy a long time whenever a cable appears to be too short, as they need to rip the cable harness open, then take it out and then get the new cable back in again. Finally, especially when using a cable harness, the cable bundles do not look as neat as they should. On the contrary an advantage of using such cable harnesses or plastic hoses would be that pulling and bundling the cables can be done outside of the dredger. By pulling and bundling outside of the dredger, the employees are not bothered by the small spaces, uneasy pathways in the dredger, and the other people working in the dredger. Moreover, the bundles can be made upfront, which is an advantage for the throughput time of the dredger.

<u>Cable gutters</u>

The second possible solution is to use cable gutters within the dredger with a covering lid on it and a hook to put the cables behind it. With the particular cable gutters with hook and lid the cables do not have to be bundled and can just be laid down in the cable gutter. However, the employees at the assembly onsite will still have to make holes within the cable gutter on the places where the cables will have to come out of the gutter. Moreover, the employees will also have to place swivels in these holes. In addition, the cable gutter will then have to be placed with the longest side vertically in the dredger, as company X would want to keep the width that the cables need as small as possible.

<u>Pipes</u>

The last solution that has been thought of, and for which most stakeholders were enthusiastic, was the option to install pipes within the dredger. These pipes should then all be three or four meters long and then an opening should take care that the cables can go out when needed. This way the cables can cross each other, as it is not visible and they do not have to be tie-wrapped about every 20 centimetres. The cable bundles will only have to be tie-wrapped on the place where the opening between the pipes are and when the cables are going to the components. Also with the short pipes a spring tension is not needed to pull the cables. Using pipes also has some disadvantages. First, on the place where the cables go out of the pipe, there will have to be some kind of protective layer, so that the cables will not be damaged by the vibrations of the dredger. In addition, when multiple cables are pulled within the pipes the pulling of the cables can become harder and take longer and longer cables are needed. The longer cables are needed, because with pipes of about 3 to 4 meters every cable cannot go directly to their destination but will have to go through the openings between the pipes.

Conclusion
With only the (dis)advantages of all three the solutions and very limited estimations of the number of saved hours it is hard to say which of the solutions would be the most beneficial for Powerspex. Therefore, I will elaborate more in the implementation plan in Section 6.1.5 on how the best solution might be found and implemented.

5.2.6 Measuring and drawing

The measuring and drawing of the mounting plates of the cabinets, the doors and the gland plates, will be standardized already with the revision. The entire process of drilling the holes will be outsourced to an engraving technique company. Therefore the processes of measuring and drawing, together with drilling the holes can be eliminated at all. The decision to outsource this entire process is already made within Powerspex, hence only this option will be evaluated.

Number of saved hours
The total number of saved hours with measuring and drawing will be about 1181 hours. Namely when all the hours spent on measuring, drawing and drilling or die-punching the holes in: the mounting plates, the doors of the electrical cabinets and the gland plates are added these 1181 hours are the result.

Investment costs
To have the plates and the doors drilled and die-punched at the engraving technique the Auto CAD drawings will have to be made. Making Auto CAD drawing will come down to an investment of hours of the hardware engineer.

Other (dis)advantages
Outsourcing the activities will cost Powerspex money, as the engraving technique company will demand extra money for their services. However, the costs for outsourcing this activity are not entirely clear.

Conclusion
In total about 1181 hours are spent on the drawing, measuring and drilling and die-punching activities, whereas the Auto CAD drawing only will have to be made once by the hardware engineer. Depending on the costs of outsourcing the activities, it is considered an effective solutions to reduce the number of working hours, especially because there are quite some hours spent on all activities together.

5.2.7 Rebuilding the LED-lights

The current LED-lights that are used within the dredger have to be rebuild before they can be used within the dredger. There is only one solution thought of, which is to buy heat resistant LED-lights that are easier to use.

Number of saved hours
When LED-lights are bought that can be easily used, there can be saved about 215 hours within the current process. Namely the process to rebuild the lights can be scrapped.

Investment costs
For Powerspex there are no investment costs involved, as company X is buying the LED-lights for Powerspex to connect them within the dredger.

(Dis)advantages
The only disadvantage of this solution is that company X will have investment costs involved and that

company X will have to have inventory of two different products for if a LED-light of a customer breaks down.

5.2.8 Conclusion

In Table 5.2:1 below, the non-value adding activity can be seen together with the recommended solution. In total all these solutions will lead to a saving of about 2,804 hours per dredger on the short-term, which will cost Powerspex a total direct investment of €33,758 and some (often negligible) indirect investments, like one-time working hours. On the long-term with the solutions of the software program and bundling the cables there can be saved up to another 1811 hours maximum, with an investment cost of at least €135,248. In total this comes down to a saving of 4,616 hours per dredger on average over an investment of €169,007. On the long-term this comes down to the fact that each saved hour will cost Powerspex about 36.6 hours.

Non-value adding activity	Solution	Number of saved hours	Investment costs
Testing and rework	To not test the PLC-related parts, but only the power supplies (short-term solution)	470 hours	-
	To develop a software program that can perform the peeping through and Proneta test at once (long-term solution)	1073 hours	€135,248
Search work	Divide the pallet in 4 compartments	403 hours	Negligible
	Using an iPad to see if the materials are already booked in	54 hours	€0, if iPad is bought for the other solution
Aftercare	Buy an iPad that is both connected to the server of Powerspex and can make pictures	81 hours	€31,826
Walking up and down the dredger	Use material boxes (that are filled in Hengelo), so the employees always have all needed materials with them	403 hours	€1,932
Bundling the cables	*To be determined*	Maximum 1208 hours	Difficult to estimate for all three the solutions
Measuring and drawing	Outsourcing the activities of drilling and die-punching	1181 hours	Hours of the hardware engineer to make the Auto CAD drawings + the extra outsourcing costs
Rebuilding the LED-lights	Buy LED-lights that are more practical to connect	215 hours	For Powerspex: €0

Table 5.2:1; All the non-value adding activities for which solutions have been found with their solutions, the number of estimated saved hours and the needed investment costs.

6 Implementation and evaluation

With the alternative solutions known and assessed for their suitability within Powerspex the next research question will have to be answered in this Chapter: 'How can the solutions be implemented and evaluated within the current production process?'. To answer this question I will first discuss in Section 6.1 how the solution can be best implemented, and what should be taken into account during the implementation of each solution. Next I will discuss the dashboard that I have made in the program Power BI in Section 6.2, which can be used to evaluate the effectiveness of the solutions on multiple areas.

6.1 RQ7a; Implementation plan

In this section the next research sub question will be answered: 'What steps are needed to successfully implement each solution in the current production process?'. Below in this Section I have written how each solution can best implemented by explaining the necessary steps. From Section 6.1.1 until 6.1.7 I will explain the implementation plans of the solutions to the next non-value adding activities respectively: testing and rework, search work, aftercare, walking up and down the dredger, bundling the cables, measuring and drawing, rebuilding the LED-lights. Finally, in 6.1.8 a conclusion is given on this Section.

6.1.1 Testing and rework

For Powerspex to make sure that the PLC-related parts are not peeped through the employees will have to be well-informed. Therefore, I would recommend Powerspex to inform their employees well that this activity is not per se needed. The supervisor in the workplace in Hengelo should be responsible for this in my eyes. In addition, I would recommend the production supervisor to keep in contact with the employees in the workplace after implementation as well if indeed not more hours are spent on finding the mistake(s) during the Proneta test than is saved by not peeping the PLC-related parts through.

For the solution of the software program that is mentioned in Section 5.2.1 I would recommend Powerspex to first start looking for a student that can function as intern for this project. A typical student that can perform an assignment like making testing software would be a student of one of the next studies: Electrical Engineering or Technical Computer Science. I would recommend a student of a higher education level ("HBO" or "WO"), as developing a testing program can be rather difficult. When a student has been found I would recommend to setup the project together with this student to see if he also sees possibilities in developing a testing program for this process. The service manager of Powerspex is held responsible for this, because he is responsible for long-term projects and because the service manager often supervises the interns.

6.1.2 Search work

When the solution with the crossbars will be implemented Powerspex will first have to make crossbars that can divide the pallet. I would advise Powerspex to simply use two pieces of wood that fit in each other to divide the materials per cabinet and DESK on the pallet. The compartments on the pallet will have to be clearly labelled, so the warehouse manager knows where he has to put the materials. In addition, Powerspex should take into account the amount of space that they have within their workplace. The crossbars will have to be installed on the pallet in a way that the pallet can still fit in the warehouse.

6.1.3 Aftercare

First Powerspex will have to buy an iPad with a protective cover. After the iPad has been bought the VPN connection can be installed so the server of Powerspex can be entered via the iPad. To have the VPN connection, the app of SonicWall Mobile Connect can be installed and used as Powerspex is using this app normally also for their VPN connections. For this the service manager of Powerspex is also responsible, because the service manager manages the (bigger) investment costs of the production process.

6.1.4 Walking up and down the dredger

Powerspex will have to purchase the material boxes first, so that the employees of Powerspex can fill up these boxes with the needed materials. To know what materials and how many materials should be put in the boxes, material lists will have to be made. The employees in the workplace in Hengelo can then use these material lists to fill the material boxes with the appropriate amount of materials. The material boxes can then be picked up by the onsite supervisor every time they are filled up. The service manager of Powerspex will be the one responsible to purchase the boxes, the supervisor in the workplace in Hengelo is responsible for the employees to fill the material boxes and the supervisor onsite will be responsible for the instruction of the employees onsite to use the material boxes.

6.1.5 Bundling the cables

To implement one of the three ideas for bundling the cables, I would recommend to first start a trial with the employees within the workplace of Powerspex. The solutions can then all three be tested, and the trial is also good to evaluate the way one of the three solutions is implemented. Sometimes when testing the idea in practice some inconveniences can show up and a lot of inconveniences can be prevented when doing a trial first. Then I would inform at Bureau Veritas (a bureau that oversees the industry norms (ISO-norms)) if the current solution is possible. If the bureau gives approval I would contact company X and other external parties to ask how much investment would be needed for each solution. Only then I would make a well-considered decision, on which solution will be implemented. If company X is also enthusiastic about the idea, I would advise Powerspex to further work out the solution and to try the solution within the real dredger, so it can be fully evaluated. The service manager will have to coordinate this, because this implementation involves interdepartmental cooperation.

6.1.6 Measuring and drawing

The service manager should carefully evaluate the outsourcing costs of replacing the activities. If the outsourcing costs become higher than the price for which Powerspex can process the plates and doors, I would consider other options. I would recommend the service manager to do it, because the project manager might be biased. The project manager was the employee that came with the idea to outsource the activities to that company.

6.1.7 Rebuilding the LED-lights

The onsite supervisor indicated that it was difficult to find LED-lights that are both heat resistant (+ 80 degrees Celsius) and easy to mount. However, I would search for alternative suppliers, that have not been contacted yet. The service manager, in coordination with the supervisor onsite would be responsible for this.

6.1.8 Conclusion

There are two solutions for which the implementation plan requires quite some attention. The implementation plan regarding the testing software requires quite some attention, because Powerspex will have to find a suitable student to develop a testing program for which a project will have to be setup. In addition, the implementation of one of the solutions for bundling the trials requires a lot of attention as a trial will have to be started, a lot of additional information will have to be known and the solutions will all have to be evaluated not only by Powerspex, but also by Bureau Veritas and company X.

6.2 RQ7b; Dashboard and evaluation

Once the solutions of this research will be implemented the solutions will have to be evaluated by the management of Powerspex. Therefore in this Section the next research sub question will be answered: 'How can the management of Powerspex effectively evaluate the (implementation of the) solutions?' For the evaluation a dashboard has been made in the program Power BI, which gives the management of Powerspex useful information about the number of hours spent in the process and the costs made within the process. By using the dashboard the management of Powerspex can possibly adjust solutions. In Section 6.2.1 and 6.2.2 I will explain a bit more about how I have divided the tabs of the dashboard and how I have incorporated a selection menu for the desired project numbers respectively. In Section 6.2.3 until Section 6.2.6 I have explained some more about what the graphs on the pages represent. The page of the profit is discussed in Section 6.2.3, after the page of the total costs will be discussed in Section 6.2.4. Next the page of the labour costs will be explained in Section 6.2.5, before the final page about the other costs is discussed in Section 6.2.6. A conclusion will be given in Section 6.2.7.

6.2.1 The tabs

The next subjects will be visualized in the dashboard: the profit margin, an analysis of the total costs, an analysis of the labour costs and an analysis of the other costs. The decision to show these subjects in the dashboard I have made after consultation with the service manager of Powerspex and after analysing the available information within the database of Powerspex. The dashboard is made in Dutch due to the fact that the retrieved data from Powerspex was in Dutch.

6.2.2 The slicer

On each page of the dashboard I have put a slicer. The slicer helps to filter the results that are represented in the graphs on the dashboard. First the slicer can filter on the start dates of the projects, so by sliding the round buttons to left and right the timeframe can be adjusted. Next the desired project numbers can be selected. Only the selected project numbers that are started within the selected timeframe are visualized.

6.2.3 The profit/loss

The first page of the dashboard, which can be seen below in Figure 6.2:1, visualizes both the profit/loss percentage and the profit/loss in euros that is made on each project. The line here represents the profit/loss in euros, whilst the bars represent the profit/loss percentage for every project.

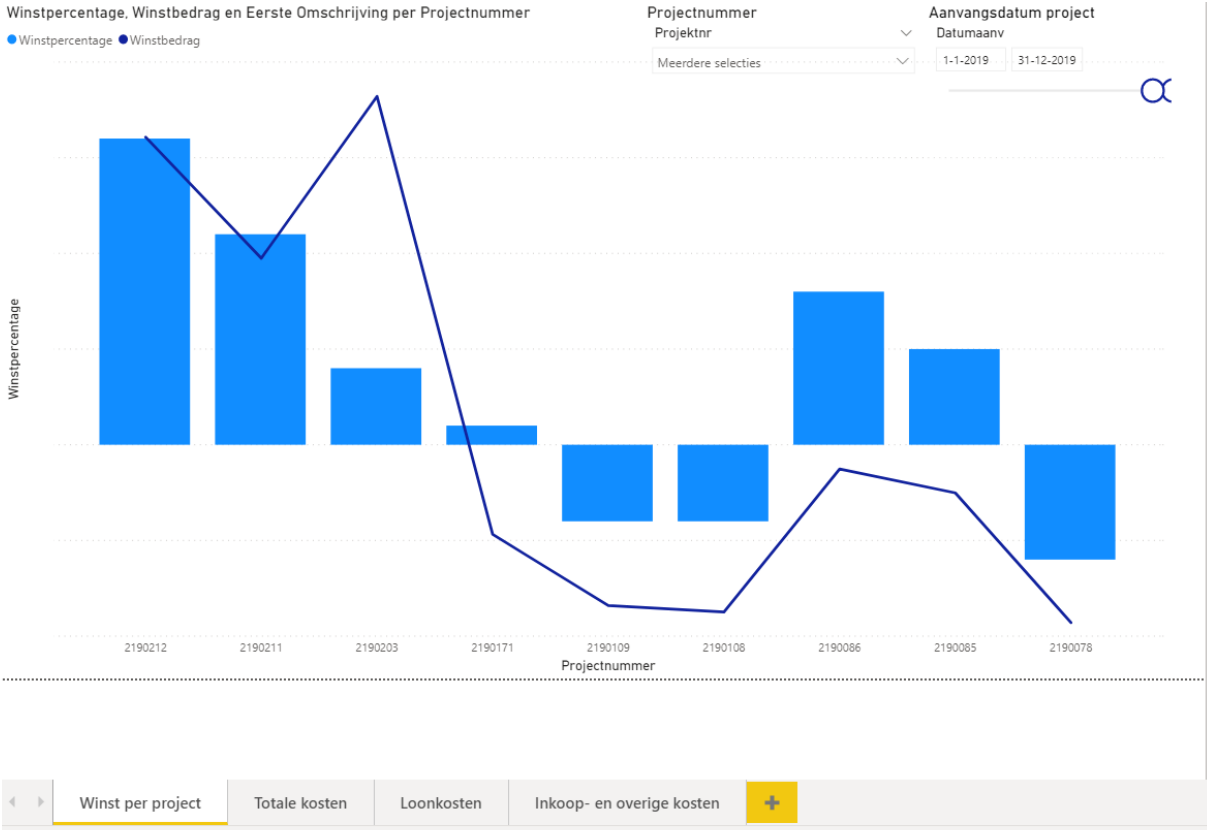

Figure 6.2:1; The first page of the dashboard in which the profit/loss percentages and numbers are shown of each project number of Powerspex.

6.2.4 Total costs

The second page contains information about the total costs of each project. In Figure 6.2:2 the second page is shown. The upper graph compares the total costs of a project with the turnover of each project. The light blue bars represent the turnover, whilst the dark blue bars represent the total costs. The graph below on the second page should visualize how much percent group of expenses equals in comparison with the total expenses for all projects that are selected in the slicer. Every number represents one group of expenses, however what each number stands for is not shown in this thesis but is known only by Powerspex itself, due to confidentiality reasons.

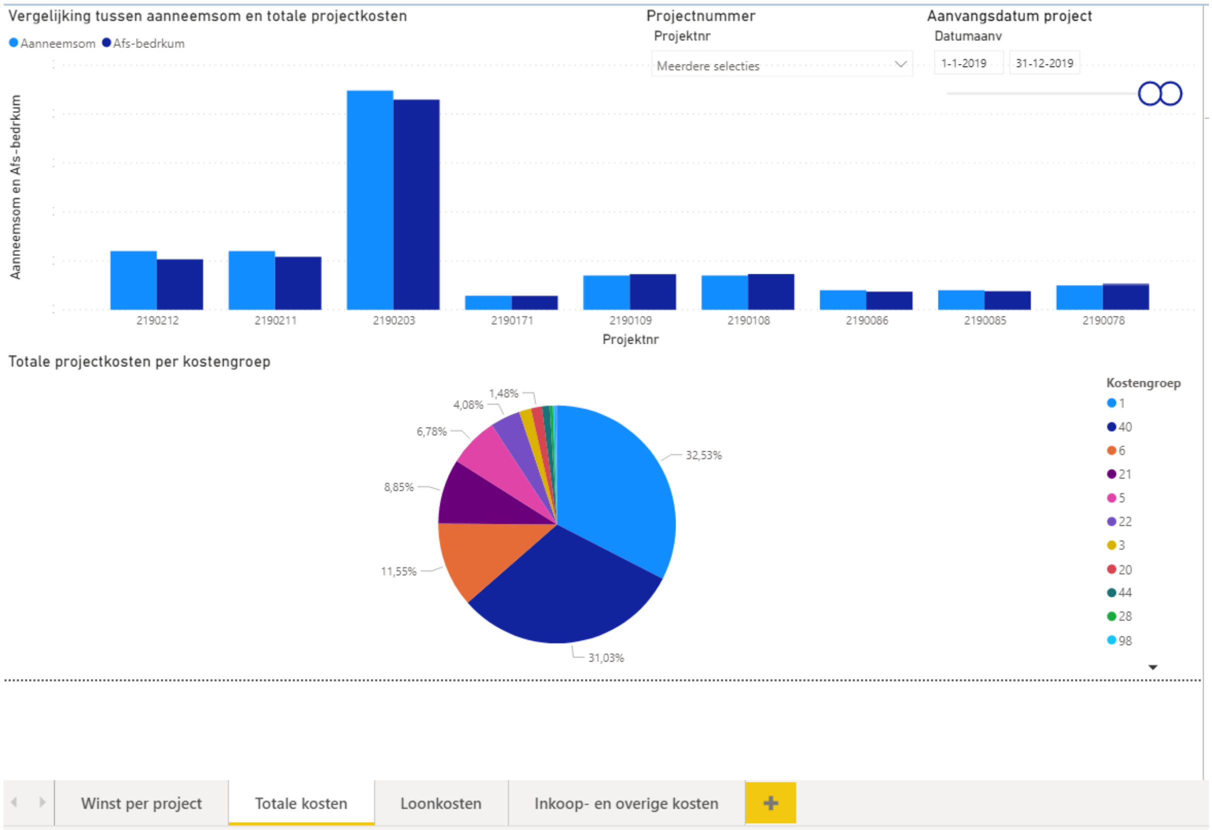

Figure 6.2:2; The second page of the dashboard on which information about the total costs of each project number is given.

6.2.5 Labour costs

The third page of the dashboard visualizes the labour costs made per project. In Figure 6.2:3 the third page is shown. The upper graph shows what the total labour costs are of each project, compared to the turnover of that specific project. The light blue bars represent the turnover, whilst the dark blue bars represent the labour costs. Next, the graph down left shows the number of hours that are made on each project compared to the total labour costs of the project. The graph tells something about the average hourly wage on each project. The line represents the total labour costs of each project, whilst the bars represent the total number of hours made on that project. When the line is above the bar, it indicates that the average hourly wage of that project was high compared to the other selected projects. Finally, the graph down on the right shows in which 'department' of Powerspex the hours are made for each project. In the graph down on the right only the numbers 1, 3, 6, 21, 22 are processed, as these represent the relevant cost groups.

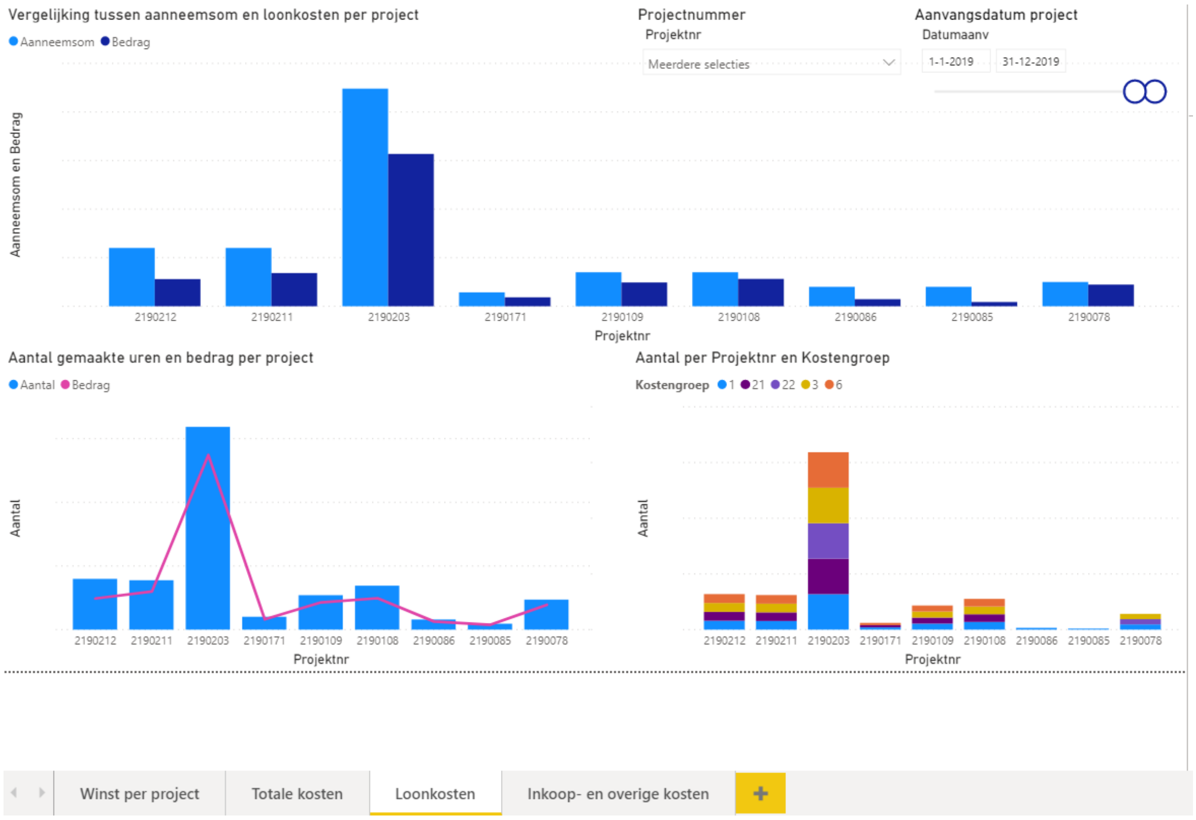

Figure 6.2:3; The third page of the dashboard on which information is displayed regarding the labour costs of each project number

6.2.6 Other costs

The fourth and last page of the dashboard, which is visualized in Figure 6.2:4, shows information about the purchasing costs and the other expenses. Both the upper and bottom graph show information about the division of the costs of each project. The difference is that the upper graph only shows the total purchasing costs and the allocation of all the purchasing costs, whilst the bottom graph shows the allocation of the total project costs. In the upper graph only the next cost groups are processed, as the rest is not relevant for this graph: 40, 41, 43, 44, 46, 47, 62.

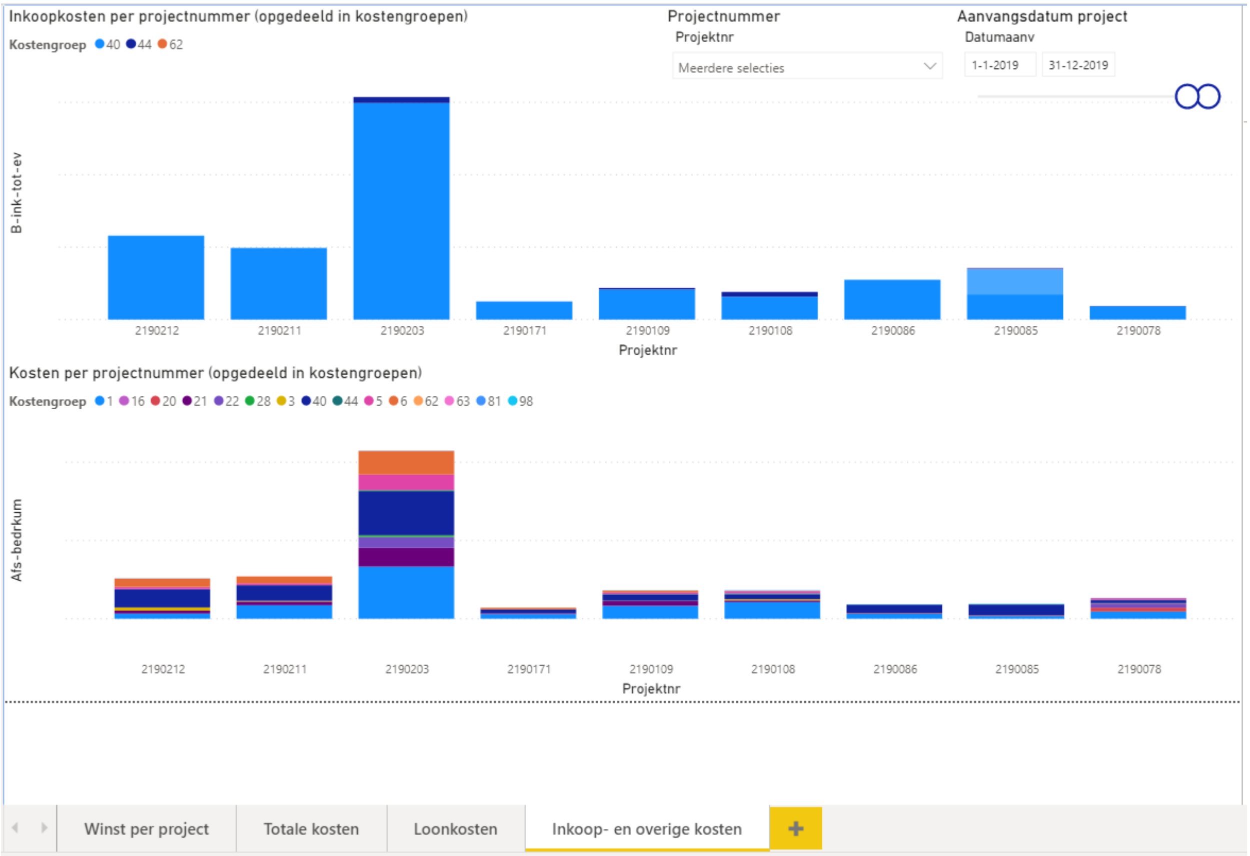

Figure 6.2:4; The last page of the dashboard on which there is information displayed on the purchasing and leftover costs of Powerspex.

6.2.7 Conclusion

The dashboard that has been made helps Powerspex to evaluate the solutions. The most useful tab for Powerspex to evaluate the performance of the solutions will be page 3, as this one gives information about the number of hours spent within the production process. When the solutions will perform well it should also show in page 1, as the profit margins will then have to go up.

7 Conclusion and recommendations

In this chapter I will discuss the outcomes of my research and conclusions that can be drawn from it. In Section 7.1 the conclusion to this research question will be given, by using the answers to research questions 1 until 7. In addition, in the conclusion the strong and weak points of this research will be discussed. Next in Section 7.2 the recommendations to the management of Powerspex are given, which are based on the conclusion discussed in Section 7.1. Finally, in Section 7.3 I will discuss the reliability and the validity of the results of this research.

7.1 Conclusion

In this Section I will answer the main research question of this research, which is: 'How can Powerspex reduce the number of working hours for the production of a dredger by improving the (production) process from a lean perspective?'. By using the answers from research questions 1 to 7 I will answer this main research question.

The process and the activity times

The current process of producing dredger hardware for a Cutter Suction Dredger can be subdivided in 8 sub-processes, which are the next ones:

1. The preparation of the production process.
2. The production of the electrical cabinets.
3. The preparation of cabling the operating cabin.
4. Cabling the operating cabin.
5. Preparing the cabling on the assembly onsite.
6. Cabling within the hull of the vessel.
7. Cabling between the operating cabin and the pontoon.
8. Commissioning the dredger (including uploading the software).

All of the sub-processes can be subdivided again in smaller activities, which are performed by 4 different departments within Powerspex. A Cutter Suction Dredger 500 can be seen as an average dredger and in 2019 the production of the hardware for this average dredger cost around 42,346 hours, according to the recalculation that I had found. However, when using the estimates of the employees I ended up at a total number of 17,550 hours spent in the process. I have not done any random measurements in the process to see if the estimates were about right and the estimates could only be retrieved from the supervisors of each department. Therefore the reliability of the time measurements can be questioned. However, the estimates are still considered useful for this research to approximate the number of saved hours within the production process.

(Non-)value adding activities

Company X beholds the product quality of their dredgers as a fundamental value for their customer. Besides the product quality company X values lower lead times, lower product prices (hence fewer working hours) and more innovation regarding both the process and the product. As long as the product quality does not suffer (too much) from the improvements company X regards it as value adding, hence there were 15 activities identified within the process that are considered non-value adding. Of the 15 non-value adding activities, 2 are considered required. The (required) non-value adding activities are the ones listed below in Table 7.1:1:

#	Non-value adding process	Required?
1	Walking up and down the dredger every time for needed tools or materials	No

2	Walking back and forth in the workplace for required materials and tools	No
3	Walking back and forth within the dredger when pulling, connecting and bundling the cables	No
4	Bundling the cables perfectly neat within the dredger and in the workplace in Hengelo	No
5	Searching the materials on the pallet of the dredger and searching for the lost materials	No
6	Measuring and drawing for drilling holes or die-punching	No
7	Fastening the tie-wraps to the cable ladders	No
8	Peeping through the cabinets, plate and the DESKs	No
9	Reconnecting the cables or resolving other faults after testing with either peeping through or Proneta	No
10	Testing the cabinets and operating cabin with Proneta	No
11	Adjust changes in electrical schemes	No
12	Rebuilding the LED-lights	No
13	Aftercare of the cabinets and operating cabin	No
14	Exporting the invoices form the supplier website to AGP	Yes
15	Creating a project number at the invoicing department	Yes

Table 7.1:1; The non-value adding activities (but required) found within the current process.

Wastes and causes

To realize a reduction of the number of working hours I have used a lean perspective and each one of the 13 non-value adding activities that have been found can be linked to three of the original lean wastes, which are: overprocessing, defects & errors, and wastes of motion. Using these three lean wastes I have made a problem cluster that enabled me to find the root causes of the non-value adding activities. The following root causes have been found:

- The employees do often not know which materials they need and how many exactly before they start the activity.
- The employees cannot (easily) see which materials are booked in.
- Booking in the materials via AGP (the ERP-program of Powerspex) is quite unpractical.
- There is not a device available in the workplace that is both connected to the server of Powerspex and can make pictures.
- The maps (with the electrical schemes) are scanned by hand.
- All materials of the dredger are put on the same pallet.

- There is not a fixed layout of the electrical cabinets.
- Not all materials are available to either automate the activity of drawing and measuring or to make the activity of drawing and measuring less time consuming.
- The current LED-lights that are used are unpractical.
- The cables have to be placed with tie-wraps on a vertical placed cable ladder.
- The cables are bundled in full-sight.
- There is a lack of standardization regarding the process and the people working on the process.
- A lot of testing the cables is done by hand, which makes it prone to human errors.
- A lot of hardware is double tested.

Solutions

To solve the root causes I have first thought of ideas myself, with the help of some stakeholders in the process. The solutions have then been evaluated during a group session with all stakeholders in the process and even new solutions have been thought of during the session. The solutions have then been evaluated by means of the number of saved costs, the investment costs and other (dis)advantages. With the assessment the results have been found that can be seen in Table 7.1:2.

Non-value adding activity	Solution	Number of saved hours	Investment costs
Testing and rework	To not test the PLC-related parts, but only the power supplies (short-term solution)	469 hours	-
	To develop a software program that can perform the peeping through and Proneta test at once (long-term solution)	1073 hours	€135,248
Search work	Divide the pallet in 4 compartments	403 hours	Negligible
	Using an iPad to see if the materials are already booked in	54 hour	€0, if iPad is bought for the other solution
Aftercare	Buy an iPad that is both connected to the server of Powerspex and can make pictures	81 hours	€31,826
Walking up and down the dredger	Use material boxes (that are filled in Hengelo), so the employees always have all needed materials with them	403 hours	€1932
Bundling the cables	*To be determined*	Maximum 1208 hours	Difficult to estimate for all three the solutions
Measuring and drawing	Outsourcing the activities of drilling and die-punching	1181 hours	Hours of the hardware engineer to make the Auto CAD drawings + the

			extra outsourcing costs
Rebuilding the LED-lights	Buy LED-lights that are more practical to connect	215 hours	For Powerspex: €0

Table 7.1:2; The non-value adding activities with their solutions, the number of saved costs and the investment costs.

Results
With the solutions represented in Table 7.1:2 on the short-term 2804 hours will be saved per dredger with a total needed investment of €33,758. However, on the long-term there will potentially be saved about 4616 hours with a needed investment of €169,007. As discussed in Section 1.4.1 the service manager of Powerspex would like to have a CSD500 built within about 32,202 hours. However, even on the long term the total number of hours saved will probably be at most 86 hours. Although this is a step in the good direction I am still not where the service manager of Powerspex would like to be. In the best case there will now be spent about 37,730 hours on a CSD500.

Implementation
The solutions have been thought of, however, the implementation and the evaluation phases of the MPSM cannot be done by myself due to time limitations of this research. However, with an implementation plan, which are especially useful for the solution of bundling the cables and the solution of developing a test software, I have advised how Powerspex can implement the solutions the best. To implement a solution for the bundling of the cables I would first do a trial to see if in practice the solutions are also good. Next to that Powerspex should find a student (an intern) that can develop a testing software for the testing of the electrical cabinets and the operating cabins.

Evaluation of the implementation
Finally, I have designed a dashboard in the program Power BI to evaluate the performance of the process after implementing the solutions. The profit margins within the first page of the dashboard should show an increasing trend, as the number of hours in the process will have to go down. To prevent Powerspex from only evaluating the number of working hours I have added multiple pages to the dashboard. With these other pages Powerspex can for example also monitor effect that the solutions have on the other costs of the projects.

7.2 Recommendations

In this section the recommendations will be given for Powerspex to reduce the number of working hours spent within the production process. The given recommendations will be based on the (conclusion of the) research.

First I have found solutions to eliminate non-value adding activities within the process of Powerspex. I would advise Powerspex to implement the following solutions within their process.

Testing the hardware
To test hardware I would advise the management of Powerspex to have the employees in the workplace in Hengelo only peeping through the parts that are related to the power supply. However, this solution is mainly considered for the short-term. For the long-term I would advise the management of Powerspex to develop a software program to test the cabinets and the operating cabin. The development of the software program can be best done by a student that is doing a study in the area of Electrical Engineering or Technical Computer Science.

Searching the materials before producing the cabinets or DESKs
Currently the warehouse manager of Powerspex puts all incoming materials of one project in the

project pallet. However, I would recommend the management of Powerspex to divide the project pallet in 4 compartments, so that the warehouse manager can divide the materials on the pallet already per cabinet or DESK. With the materials already subdivided on the pallet, the employees in the workplace do not need to search the materials on the pallet every time. With 4 compartments the next division is recommended: the SK100 and the SK250 together, the SK200 and the SK300 together and the DESKs both in a separate compartment, as this saves the most time. Also I would advise Powerspex to use an iPad with the program AGP on it, so the employees can check if the materials not present on the pallet are already booked in or not.

Aftercare
To make the pictures and the scans of the maps within the workplace in Hengelo I would advise the management of Powerspex to purchase an iPad. The iPad can be easily connected to the VPN and the pictures can be easily uploaded to the Powerspex server. The maps with the electrical schemes can also be downloaded from the server on the iPad and be adjusted on the iPad if needed, so that the maps do not have to be scanned in every time.

The use of material boxes
At the assembly onsite I would advise Powerspex to purchase about three material boxes (one for every employee, as there are about three employees on average). The material boxes can then be filled in the workplace in Hengelo, where material lists will have to be made for the activities done at the assembly onsite. By using the filled material boxes at the assembly onsite the employees do not need to walk up and down the dredger constantly for needed materials.

Bundling the cables
Three solutions were considered to eliminate the activities of bundling the cables (overly neat). However, I have not been able to choose one of the three solutions due to the fact that these solutions cannot be evaluated in theory. To evaluate the three solutions of: using cable harnesses, using pipes of about 3 to 4 meters and using cable gutters, I would recommend to the management of Powerspex to do a trial first. During the trial employees of Powerspex will have to try the solutions, so the solutions can be improved and evaluated by means of the number of hours spent on the activity. Before one of the solutions will be chosen I would advise the management of Powerspex to first check with the regulations of Bureau Veritas if the solution can indeed be implemented. Furthermore, I would advise the management of Powerspex to contact company X and external parties for the possibilities and the required investment costs, before a final solution would be implemented.

Outsourcing the activities
The outsourcing of the activities of measuring, drawing and drilling or die-punching the plates and doors is considered an effective method to reduce the number of working hours. However, I would recommend the management of Powerspex to carefully check the (extra) costs of outsourcing this activity. If the outsourcing costs are quite high the activities can maybe be better done within Powerspex. Of course Powerspex can reduce the number of hours spent on these activities then by using a fixed layout of the cabinets and using moulds to draw and measure the plates and doors.

Finding other heat resistant LED-lights
To prevent the employees at the assembly onsite to rebuild the LED-lights before they can be mounted to the hull of the vessel I would recommend the management of Powerspex to find another LED-light that is heat resistant to 80 degrees Celsius. Then Powerspex will have to propose the option to company X, so the activity can be eliminated from the process.

Evaluating the solutions
To evaluate the solutions I would recommend the management of Powerspex to keep an eye on the dashboard that I have made in Section 6.2. After implementation of the solutions the dashboard should visualize higher profit margins, and especially lower labour costs. Therefore page 3 of the dashboard is rather important, as the labour costs are displayed on that page.

Number of hours per activity
What has been noticed is that the project manager does not exactly know how the hours are spent within the production process and he does not exactly know how long each specific activity takes within the process. The measurements within this research are done by asking time estimates from the employees due to time limitations, however these measurements do not add up. This means that within the process there is more time spent, but it is not exactly clear to which activities this time is spent. That is why I would also recommend to literally measure how long each activity takes within the process.

Additional methods for hour registration
I have noticed that currently it is difficult for the hardware engineer (also functioning as the project manager) to keep track of where the number of hours are spent within the process. At the moment all employees fill in their hours and they have a number that is paired up with their function within the company. For example the hardware engineer has a fixed number which is linked to his function and when he will register his hours in AGP, it will all be put in the project as hardware engineering. However, he is doing more than only hardware engineering. He is namely also busy with ordering the materials, with the management of the projects, etc. Also when for example an employee that normally works at the assembly onsite, is helping with the commissioning then he cannot register his hours under the commissioning. This way it is difficult to see where the number of hours in the process occur, and also how they can be reduced then.

7.3 Discussion

In this section the reliability and the validity of the results of this research will be discussed. During the research measurements are performed and assumptions have been made. To evaluate the results of this research the assumptions and the measurements will have to be assessed for their reliability and validity.

Within this research a lot of the number of saved hours are estimated by using estimates of only one employee in the concerning department. Only using the time estimates of one employee and not performing (additional) measurements can pose a threat to the reliability of the measurements of the activity times and to the estimated number of saved hours of each solution. The actual number of spent hours within the production process is known, hence the measurements are evaluated during the research on their validity. However, the measurements do not add up in the end.

With mapping out the processes and measuring the activity times I have used the production process of the hardware of a CSD500. The CSD500 is the most produced and is seen as the average dredger regarding the number of working hours that have to be spent on producing the hardware of a CSD. Although the employees have been telling me that the process and the activities are almost the same, except for a few (small) activities it might be the case that the allocation of the working hours is very different for the other dredgers, hence also the number of saved hours. This means that the incentive to implement some solutions might be very different and that the recommendation might also have been very different from the current recommendation to implement the solutions.

Despite the issues addressed regarding the reliability of the time measurements, the measurements can be used to evaluate the number of saved hours. The solutions are evaluated by the number of saved hours, however when the time measurements vary somewhat from the reality I think that it will have little influence on the assessment of the solutions.

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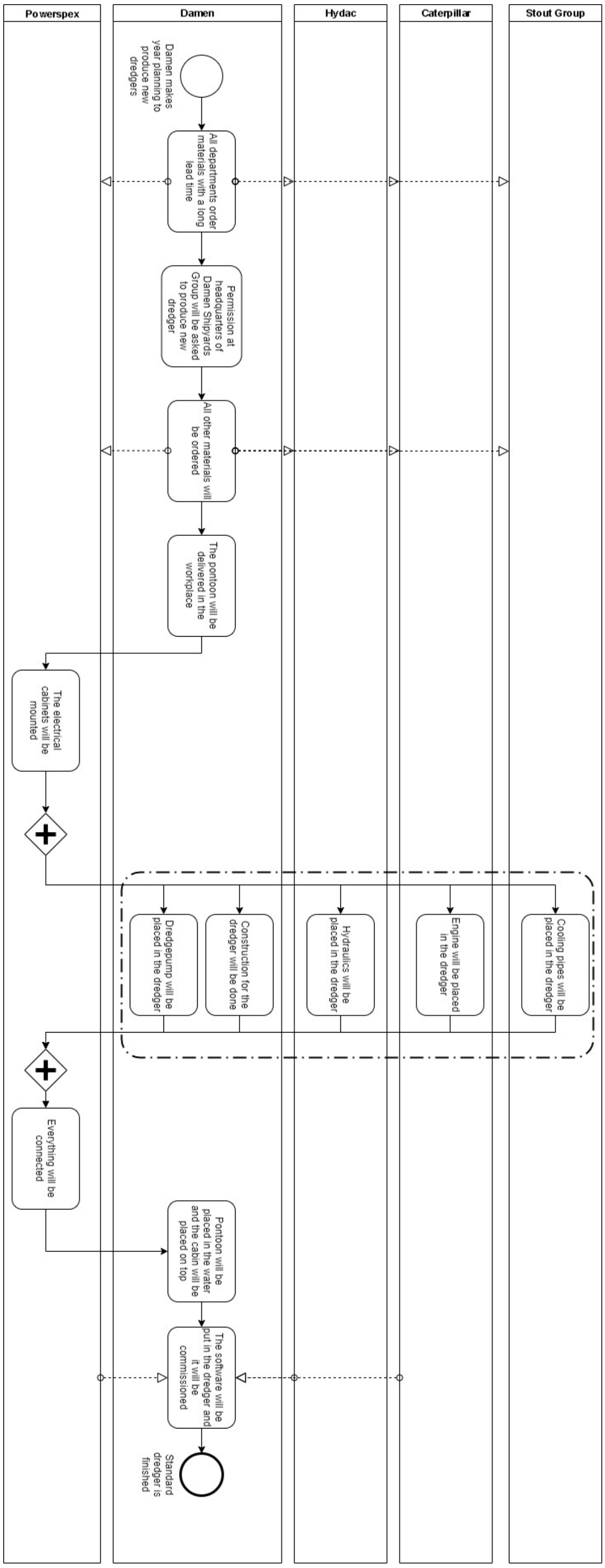
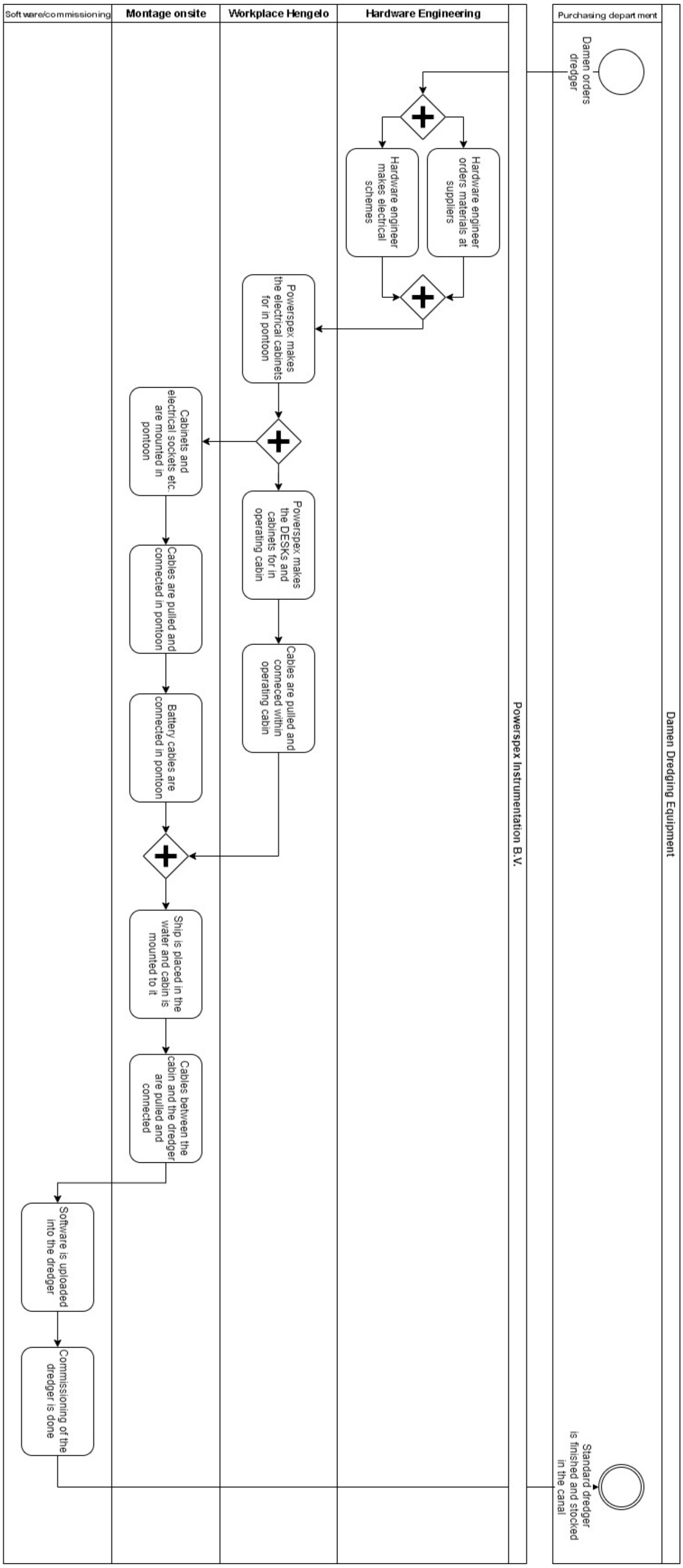
Appendices

Appendix A (the horizontal process maps)

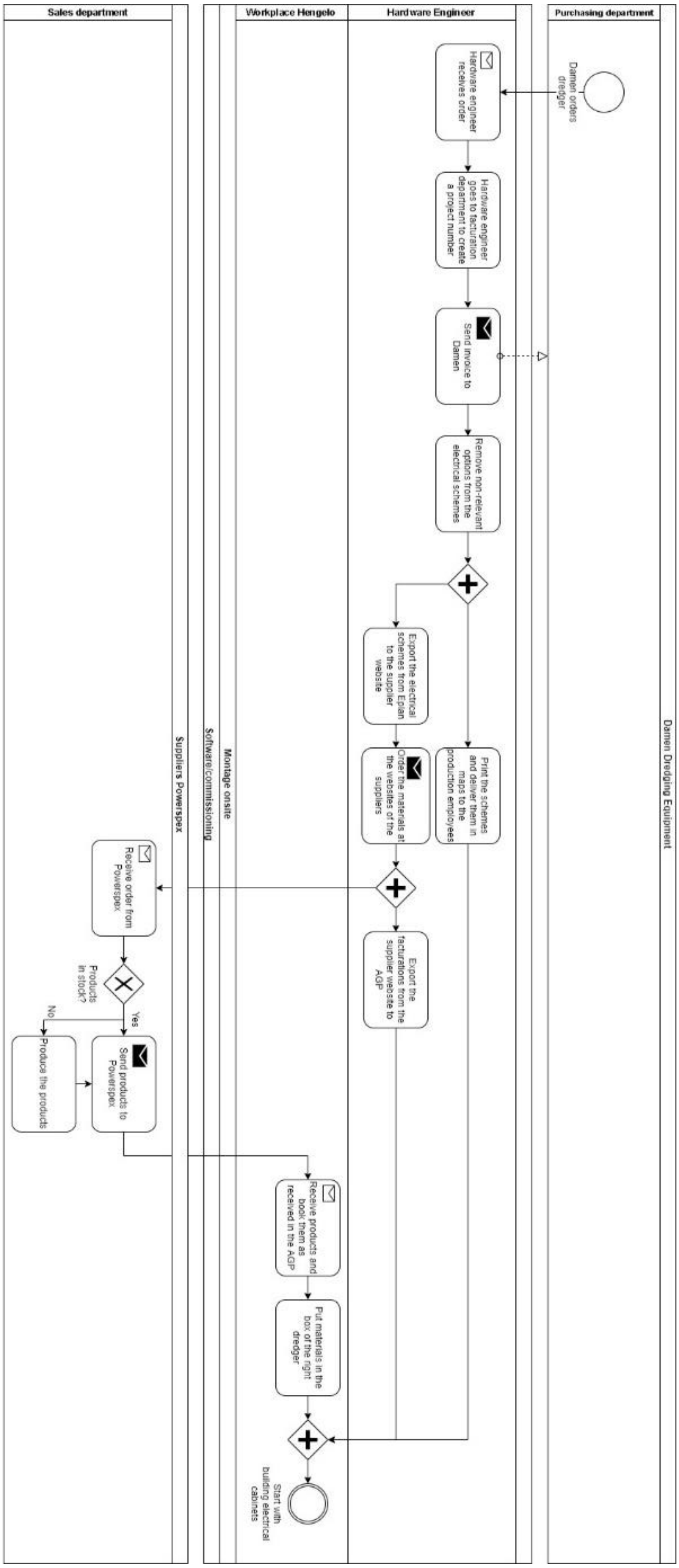
The production process of a dredger



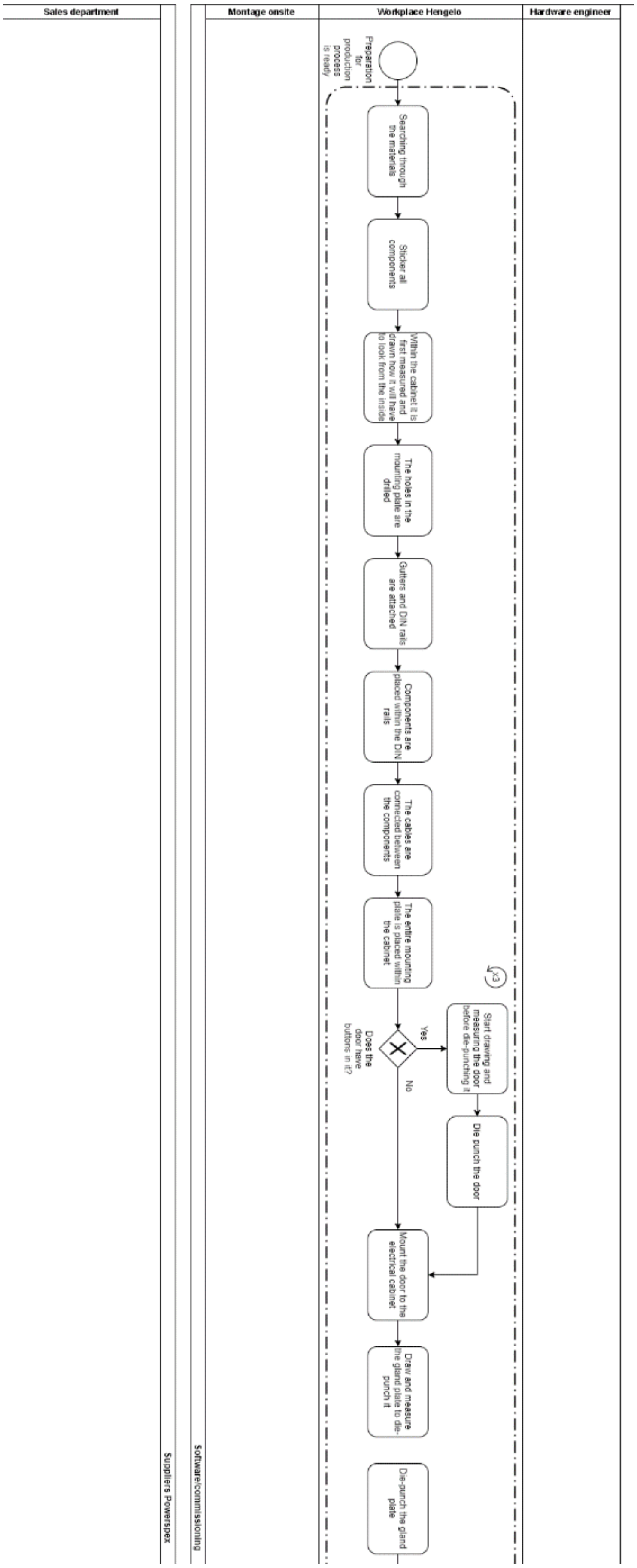
The overall process of Powerspex



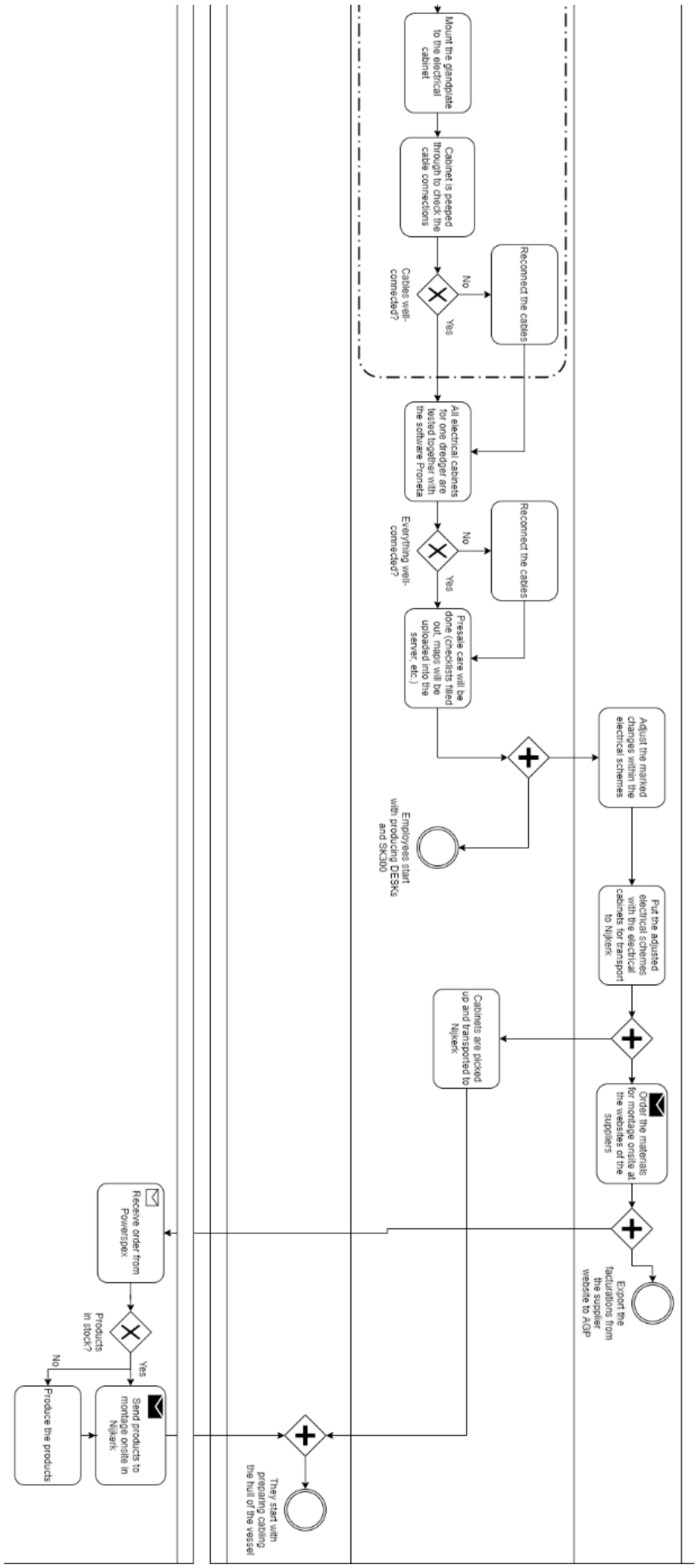
The preparation of the production process



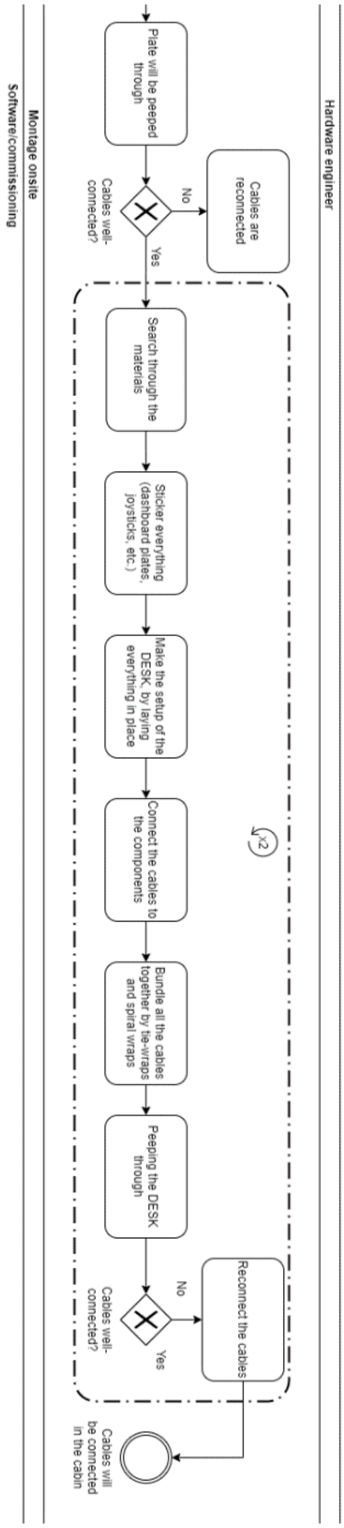
The production of the electrical cabinets (part 1)

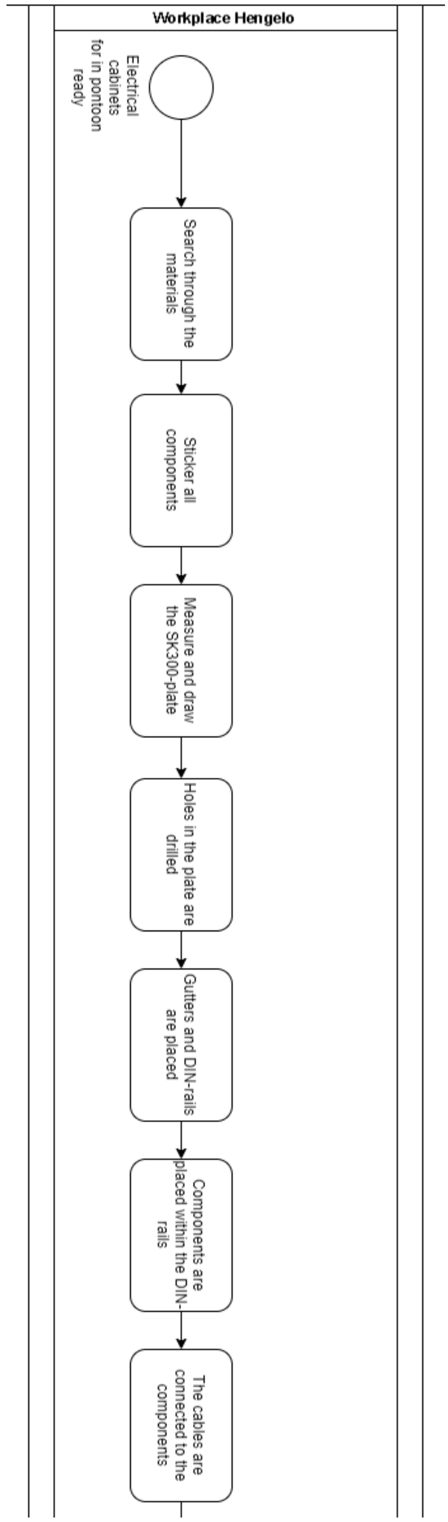


The production of the electrical cabinets (part 2)

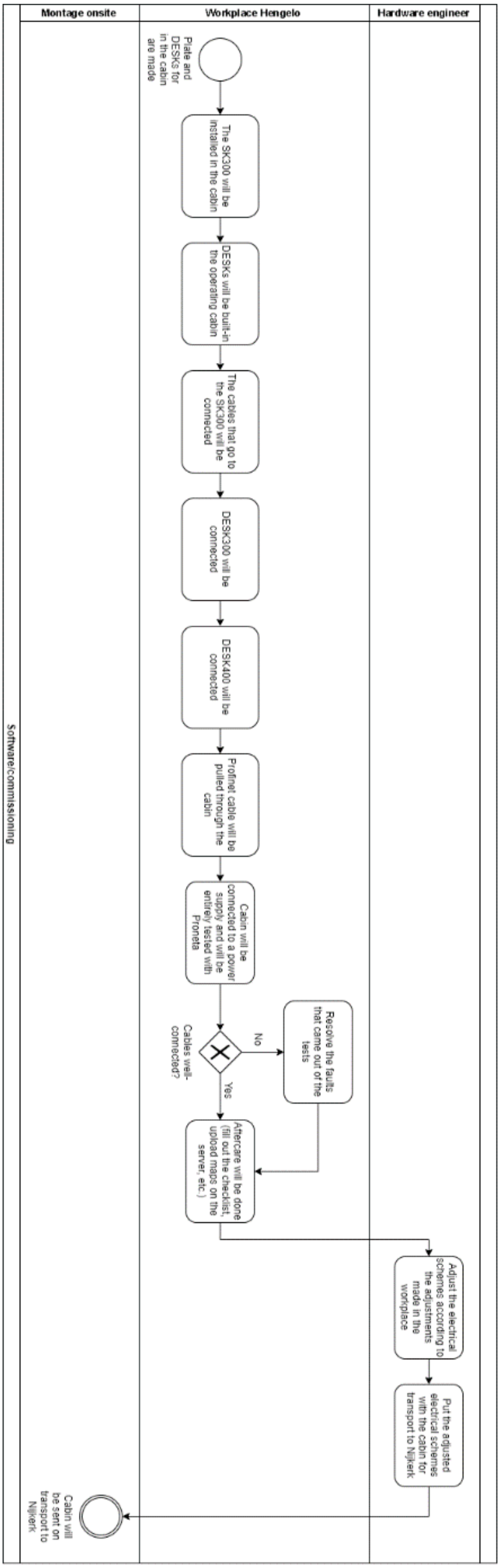


Preparation of cabling the cabin

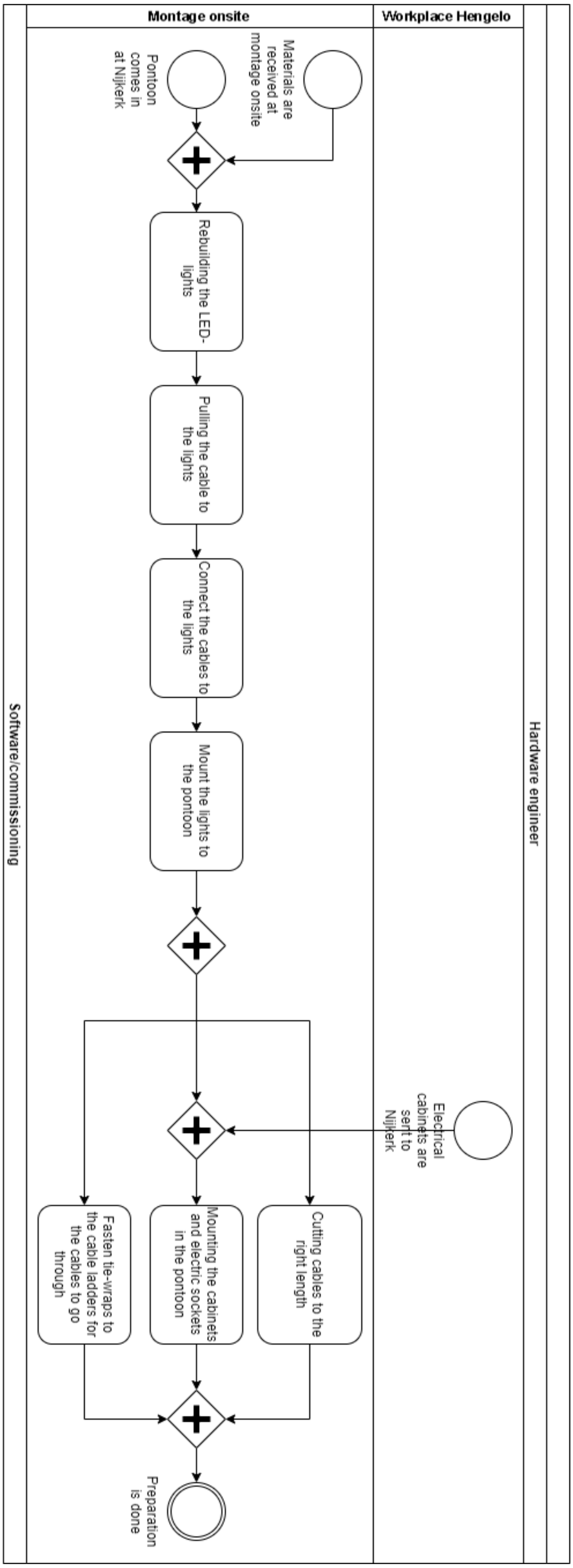




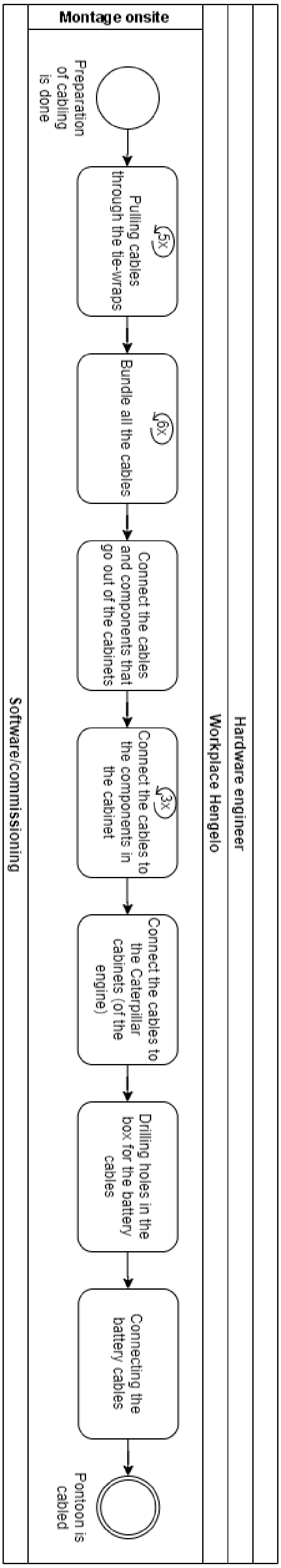
Cabling the operating cabin



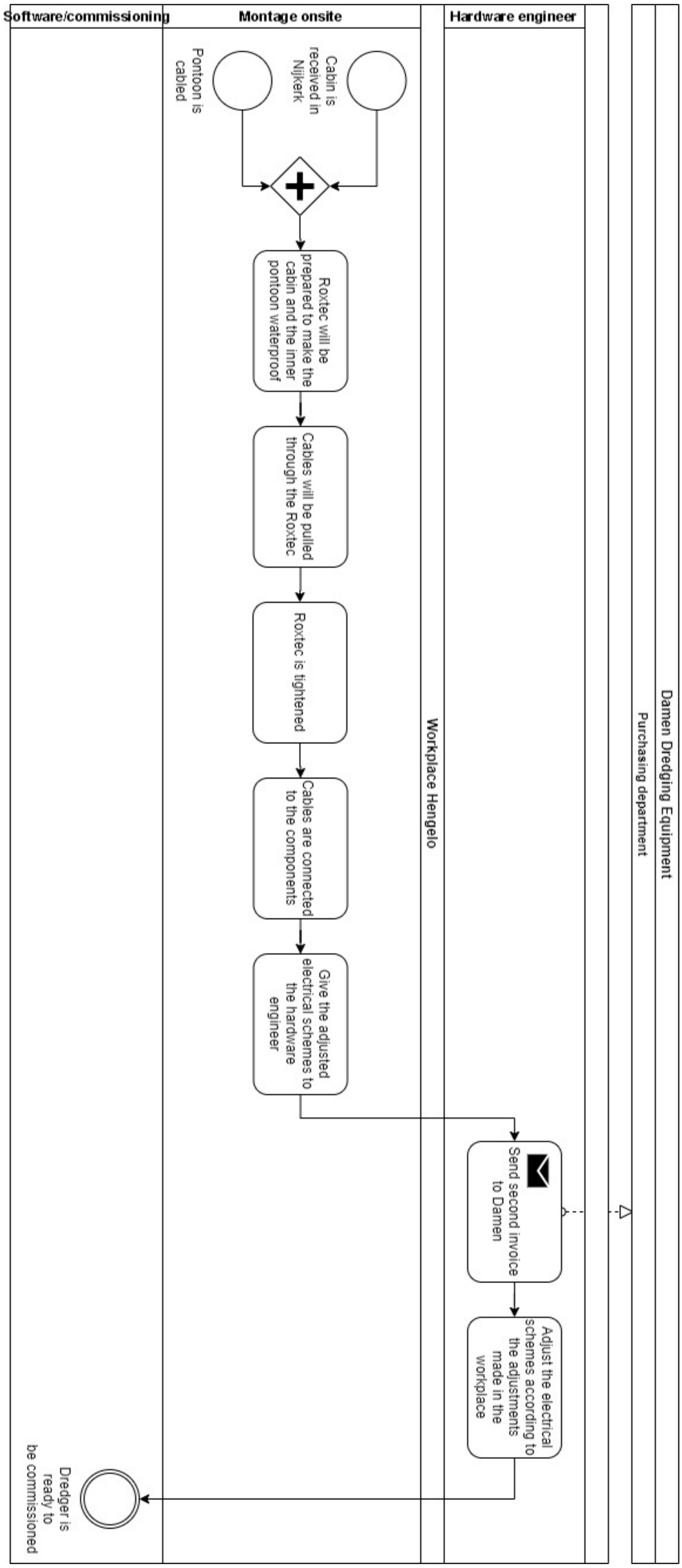
Preparing the cabling at the assembly onsite



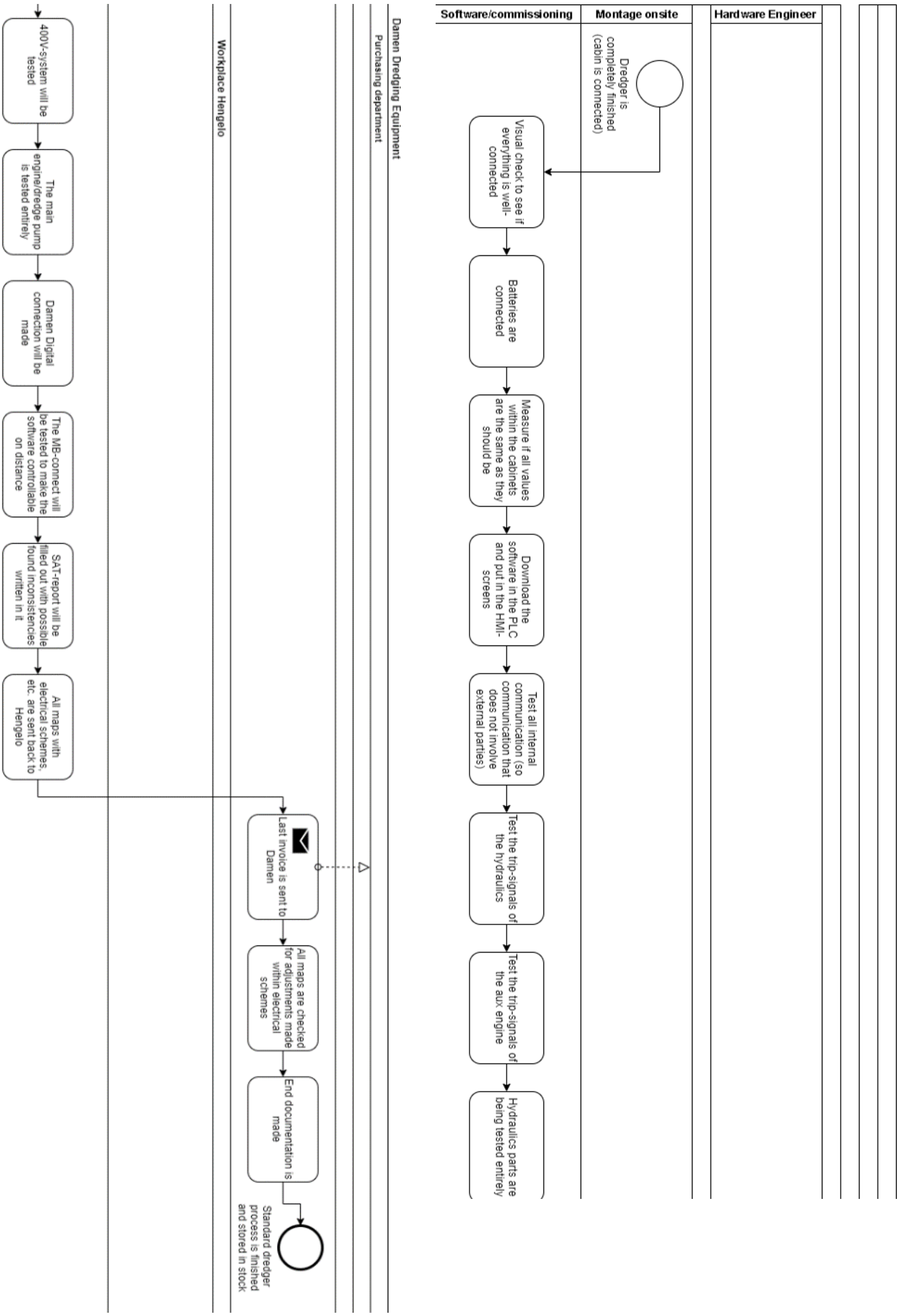
Cabling within the hull of the vessel



Cabling between the operating cabin and the pontoon



Commissioning the dredger



Appendix B (Business Process Modelling Notation 2.0)

First the choice for the Business Process Modelling Notation 2.0 is explained, before all symbols of the BPMN2.0 that are used in this report are described below. These symbols are explained as described by the Object Management Group (2006).

The choice of the BPMN2.0 language

The BPMN2.0 is a modelling language that is used industry wide and amongst many academics, hence it is labelled as an ISO Standard (Geiger, Harrer, Lenhard & Wirtz, 2018). BPMN2.0 tries to establish a standard modelling language to be used, across the entire industry (Geiger, et al., 2018). This causes the fact that the modelling language is relatively plain and simple, so that all stakeholders in a process can easily understand it. It also causes the fact that the modelling language can be of good use to visualize and evaluate the information of a business process regarding quality, costs or time (Martins, Lopes & Santos, 2019). Moreover, BPMN2.0 provides the option of having sub-processes modelled as a compound process, so that the degree of detail of the process model can be as desired (Corradini et al., 2020).

Due to the high degree of accessibility and the possibility to incorporate a high degree of detail in the business process models, BPMN 2.0 is chosen to visualise all the processes within this research. The BPMN2.0 language is fully explained in Appendix B.

BPMN2.0 language explanation

The first BPMN-symbols are the events which indicate the happening of something, which either have a trigger or a result. The start event symbol indicates the start of a particular process. Whereas the end event symbol indicates the end of a process. The intermediate event however appears between a start and end symbol, as it does not immediately terminate or start a process. Further the message symbol indicates that a particular message is triggering the process. All the event symbols are visualized in Figure 1.

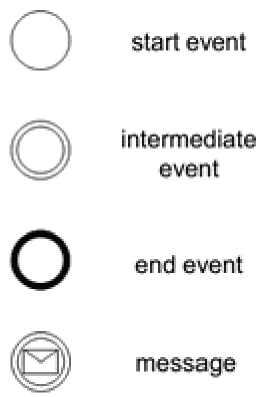


Figure 1; The events.

The next symbols are the tasks. Which are described as atomic activities. This means that these activities are not broken down further into smaller sub processes. The receive task and the send task symbols indicate an activity in which the actor will either receive a task or send a task, as the name already tells. All the task symbols are shown in Figure 2.

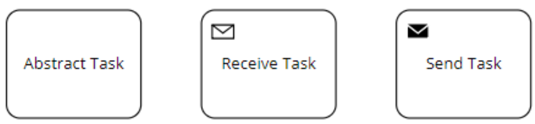


Figure 2; The tasks.

Further the sequence flow indicates the order in which the activities are to be performed within a process. Whereas the message flow indicates the communication between the participants within a process. Both the flow symbols are represented in Figure 3.

Figure 1; The flows.

A pool then again indicates the different participants within a process. A pool can contain multiple lanes again, which help to organize activities within the process. Another symbol that helps to categorize activities within the process is the group-symbol. This symbol does not affect the flow, however. A pool, with swimming lanes in it is given in Figure 4, whereas the group symbol can be seen in Figure 6.

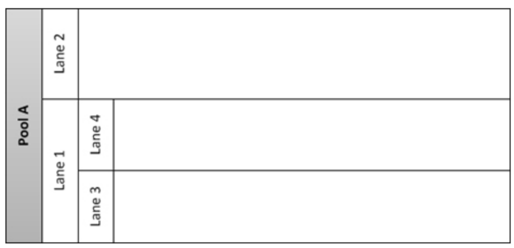


Figure 2; The pool and swimlanes.

Then the gateways that are used within this process map are the exclusive gateway and the parallel gateway. Gateways do influence the sequence flow of the process, both the in- and the out coming ones. The exclusive gateway only splits the flow into one way or only needs one way as input, whereas the parallel gateway can go multiple ways and can also join multiple ways. The gateways are visualized in Figure 5 below.

Finally the looping-symbol indicates the repetition of a task, which can be seen in Figure 7 below.

Figure 5; The loop.

Figure 3; The group.

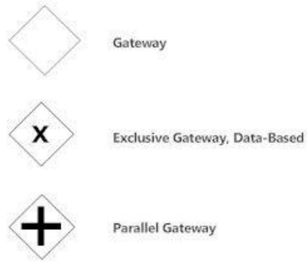


Figure 4; The gateways.