Rework Process

Determining the Current State of the Rework Process and Developing a New Process that Enables Transparent Rework at GE Healthcare Umeå

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This master thesis is the result of the final course of Industrial Design Engineering at Luleå University of Technology. It was a project conducted from January to May in 2015 at GE Healthcare in Umeå. The project concerned the process of rework at the site.

We want to give thanks to Andreas Parment and Sara Lagerfelt at GE Healthcare for their patience while supervising us. We also want to give thanks to Jan Johansson at Luleå University of Technology for the advice and guidance he offered us during our supervisory meetings. Finally we want to thank all the employees at GE Healthcare that enabled this project by answering our questions, partaking in interviews, surveys, focus groups and other meetings.

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Abstract

One of GE Healthcare’s goals 2014 was to reduce the amount of rework with 10%. When the company initiated the work towards this goal, they suspected that the registered data of the amount of rework did not comply with the actual amount of rework. They believed that in order to reduce the amount of rework, they first had to ensure that gathered data complied with the reality. That is where this thesis project enters. The purpose of this project is to define the current state of the rework process in the whole factory and to determine the definition of rework. It is also to develop and create a requirements specification and a concept for a new rework process that makes the amount of rework transparent for the organization.

Interviews, observations and surveys were conducted at the company in order to map the current state of the rework process. The gathered data was analyzed and resulted in a requirement specification, which became the foundation of the following concept development. Two focus groups with employees at the site were conducted in order to intercept ideas and requests of a future rework process and registration system of rework. Three concepts were developed and then compared against each other in a selection analysis. One concept was chosen for further improvement work and validation. Finally, a recommendation was formed to the company.

The mapping of the current state revealed that the current process is inconsistent and complex. The system for registration of non-conformances, called NCR, is complicated and troublesome to use. The process needs to be standardized and the NCR needs to be simplified. The developed concept contains both a standardized process and a simplified NCR. The concept also eliminates a non-value adding activity which means that the NCRs will be processed quicker. Finally does the new concept implicate that the creator of each NCR will receive feedback of the taken approach as a result of the NCR.

KEYWORDS: Rework, Non-conformances, Process Mapping, Industrial Design Engineering, Lean Six Sigma, General Electric Healthcare, Concept Development, Focus Groups
Sammanfattning

Ett av GE Healthcares mål för 2014 var att minska mängden omarbete med 10 %. När arbetet med att uppnå detta mål påbörjades upptäcktes det att registrerad data som skulle motsvara mängden omarbete i fabriken rimligtvis inte kunde stämma överens med verkligheten. Företaget bestämde att de måste se till att registrerad data stämmer med verkligheten, innan de kan försöka minska omarbetet. Det är här detta projekt kommer in. Syftet med det här projektet är att klargöra nuläget av omarbetsprocessen i fabriken och att skapa en definition av omarbete. Syftet är också att utveckla en kravspecifikation och ett koncept för en ny omarbetsprocess som gör att omarbetet i fabriken transparent.


**NYCKELORD:** Omarbete, Avvikelser, Processkartläggning, Teknisk Design, Lean Six Sigma, General Electric Healthcare, Konceptutveckling, Fokusgrupper
# Content

1 INTRODUCTION.................................................................................................................. 1

1.1 PROJECT INCENTIVES................................................................................................... 1

1.2 PROJECT STAKEHOLDERS.......................................................................................... 1

1.3 PROJECT OBJECTIVES ANDAIMS............................................................................. 2

1.4 PROJECT SCOPE.......................................................................................................... 2

1.5 THESIS OUTLINE......................................................................................................... 2

1.6 TERMINOLOGY............................................................................................................. 3

2 COMPANY PRESENTATION............................................................................................... 4

2.1 GENERAL ELECTRIC..................................................................................................... 4

2.2 GEHC'S VISION........................................................................................................... 4

2.3 GEHC IN UMEÅ........................................................................................................... 5

3 THEORETICAL FRAMEWORK.......................................................................................... 6

3.1 LEAN SIX SIGMA......................................................................................................... 6

3.1.1 Right the First Time & Muda.................................................................................. 6

3.1.2 Predictability & Efficiency...................................................................................... 7

3.1.3 Standardized Flexibility........................................................................................ 7

3.2 VALUE STREAM MAPPING.......................................................................................... 7

3.2.1 Current State Map.................................................................................................. 8

3.2.2 Future State Map.................................................................................................... 9

3.2.3 Advantages and Disadvantages of VSM............................................................... 10

3.3 SUMMARY AND REFLECTION................................................................................... 10

4 METHOD........................................................................................................................... 11

4.1 PROJECT PLANNING..................................................................................................... 11

4.2 PROCESS AND CONCEPTUAL PLANNING ................................................................ 11

4.3 PHASE 1 - DETERMINING THE CURRENT STATE...................................................... 12

4.3.1 Mapping ................................................................................................................ 12

4.3.1.1 Interviews ........................................................................................................ 12

4.3.1.2 Observations .................................................................................................... 13

4.3.1.3 Surveys ............................................................................................................. 14

4.3.2 Compilation ............................................................................................................ 15

4.3.2.1 Data Compilation ............................................................................................ 15

4.3.2.2 Process Mapping ............................................................................................ 15

4.3.3 Analysis.................................................................................................................. 16

4.3.3.1 Stream Mapping ............................................................................................. 16

4.3.3.2 Data Analysis ................................................................................................ 17

4.4 PHASE 2 - IMPROVEMENT WORK.......................................................................... 17

4.4.1 Focus Groups ......................................................................................................... 17

4.4.1.1 Focus Group 1 .................................................................................................. 18

4.4.1.2 Focus Group 2 .................................................................................................. 19

4.4.2 Definition of Rework ............................................................................................ 20

4.4.3 Requirement Specification....................................................................................... 20

4.4.4 Creative Methods.................................................................................................... 21

4.4.5 Selection Method.................................................................................................... 21

4.5 PHASE 3 - TESTING................................................................................................... 21

4.5.1 The Prototype........................................................................................................ 21

4.5.2 Validation................................................................................................................ 22
List of figures

FIGURE 1. THE FOUR EXPRESSIONS FORMED BY GEHC (GEHC, 2015). ............................................................. 5
FIGURE 2. COMPANY HIERARCHY AT GEHC UMEÅ (EJDERHOV AND ÅKERLUND, 2015). .............................. 5
FIGURE 3. TOOLS THAT ARE TYPICAL FOR SIX SIGMA, LEAN PRODUCTION AND LEAN SIX SIGMA (SALAH ET AL., 2010). .............................................................................................................. 6
FIGURE 4. STEPS FOR THE VSM-CONFIGURATION (BELLGRAN AND SÄFSTEN, 2005) ............................................. 8
FIGURE 5. RECOMMENDED SYMBOL (BRAGLIA ET AL., 2006). ........................................................................ 8
FIGURE 6. RECOMMENDED SYMBOLS (BREYFOGLE, 2003). ......................................................................... 9
FIGURE 7. EXAMPLE OF A VSM (CHEN ET AL., 2010). .................................................................................. 9
FIGURE 8. REMODULED TEMPLATE WITH INSPIRATION OF CLELAND’S PROCESS TREE (EJDERHOV AND ÅKERLUND, 2015). ........................................................................................................... 11
FIGURE 9. ASSIGNED MATERIAL FOR THE FOCUS GROUP PARTICIPANTS TO USE WHEN CATEGORIZING THE REWORK ACTIVITIES AND THEN DEVELOPING NEW PROCESS FLOWS (EJDERHOV AND ÅKERLUND, 2015). ........... 19
FIGURE 10. ESTABLISHED PROCESS MAP OF THE CURRENT STATE (EJDERHOV AND ÅKERLUND, 2015). ............. 32
FIGURE 11. SM-CATEGORIZATION DEVELOPED DURING FOCUS GROUP 1 (EJDERHOV AND ÅKERLUND, 2015). .... 36
FIGURE 12. FSM DEVELOPED BY THE FIRST GROUP (EJDERHOV AND ÅKERLUND, 2015). ............................... 38
FIGURE 13. FSM DEVELOPED BY THE SECOND GROUP (EJDERHOV AND ÅKERLUND, 2015). ............................. 38
FIGURE 14. SM DEVELOPED BY THE PROJECT MEMBERS (EJDERHOV AND ÅKERLUND, 2015). ......................... 44
FIGURE 15. PROCESS FLOW FOR THE FINAL CONCEPT (EJDERHOV AND ÅKERLUND, 2015). .............................. 49

Appendices

Appendix 1: Gantt Chart ................................................................. 1 page
Appendix 2: Conceptual Process Planning .................................... 1 page
Appendix 3: Survey – Blue Collar Workers ................................. 5 pages
Appendix 4: Survey – White Collar Workers ............................... 5 pages
Appendix 5: Stream Mapping Categories .................................... 1 page
Appendix 6: Current NCR-form .................................................... 1 page
Appendix 7: NCR-prototype ......................................................... 3 pages

Appendix 3: Survey – Blue Collar Workers (5 pages)
Appendix 4: Survey – White Collar Workers (5 pages)
Appendix 5: Stream Mapping Categories (1 page)
Appendix 6: Current NCR-form (1 page)
Appendix 7: NCR-prototype (3 pages)
1 Introduction

Ask any employee at any manufacturing business about “rework”, and you will probably get the answer that it should not exist. Most businesses would probably also like to decrease the amount of rework. General Electric Healthcare in Umeå, hereinafter named GEHC, is one of them. But before one can even start thinking about decreasing rework, one must define what rework actually means and what it comprises. That is where this master thesis comes in; one of its main objectives is to define what rework is at the site in Umeå. The result of this project is supposed to make it possible for GEHC to improve their rework process.

This master thesis work is part of the final course of the Master of Science in Industrial Design Engineering at Luleå University of Technology, named A7009A. The course covers 30 credits and was executed at GEHC in Umeå in the spring of 2015. The project was conducted at full-time during 20 weeks.

1.1 PROJECT INCENTIVES

One of GEHC’s goals for 2014 was to reduce the amount of rework with 10% by the end of the year. But when the work to fulfill this goal began, GEHC realized that the definition of rework and the process of rework were unclear. GEHC also suspected that the registered amount of rework was not true compared to reality. Hence, it would be impossible to achieve the desired goal under these circumstances.

The assignment for this project is therefore to determine a definition of rework and to map the actual rework process as it looks like today. The intention of the assignment is to develop a future logging system that enables transparent rework. GEHC wants a system that both show the genuine amount of rework as well as information of each rework case, such as cause and effect.

1.2 PROJECT STAKEHOLDERS

The employer of this project is the manager of Project and Process Operations at GEHC in Umeå, Sara Lagerfelt. Interested parties are basically the whole site, since the matter of this project affects the whole factory. However, the mapping of rework distinguished a cluster of parties that came to be affected in larger extent than others. The most important of these are the Manufacturing Engineers (MEs), the assemblers and the operators, since a selection of these parties came to be involved in focus groups and validation of the improvement work.

The management of the site along with the MEs and Business Team Leaders (BTLs) are defined as users in this project, since these are the persons that will use the information that will be available as a result of this project. The assemblers and operators can be considered to be users too, since they along with the MEs will be the ones who log the rework most frequently. The target group comprises the whole site, since this project affects almost every instance of the site, and because future improvements based on this project’s outcome will involve the whole
Another stakeholder is Luleå University of Technology, since this project is performed as a course at the university. This means that the university imposes some requirements on the project, which have influenced both execution and result to some extent.

1.3 PROJECT OBJECTIVES AND AIMS
The purpose of this project is to define the current state of the rework process in the whole factory and to determine the definition of rework. It is also to develop and create a requirements specification and a concept for a new rework process that makes the amount of rework transparent for the organization. With this achieved GEHC will be able to carry through further improvements of rework.

To satisfy this purpose, the project is going to investigate the following issues:

- What is the current state of the rework process at GEHC?
- What is GEHC’s definition of rework?
- How should a process be designed to establish a transparent and real picture of the amount of rework?

1.4 PROJECT SCOPE
This project has been assigned a total of 1600 working hours (800 hours per project member) and was conducted at full-time during 20 weeks. The project work was mainly executed from the site in Umeå, but since the external supervisor is at Luleå University of Technology, the work was conducted from Luleå on Fridays.

The current state of the rework process includes filling out a form called NCR-form, or non-conformance report, which contains information about the non-conforming material in question. The software for these forms is to be replaced, and another project team at the site is looking into this. That is why this thesis does not attend possible software for NCRs. However, the result of the project can be used as guidelines when investigating which software to use.

The project described in this thesis will not attend the process for PCAs (Printed Circuit Assemblies). This is because improvement work of the process is conducted by another project team at the same time as this project. This project will neither attend the decision making process regarding whether to scrap or rework non-conforming material, because of the fact that this process precedes the rework process, and thus not considered as a part of it. Finally, this project will not attend the process of Goalseal.

The outcome of this project will hopefully allow GEHC to perform the necessary improvements to achieve one of their internal objectives of 2014. However, this project will not perform these improvements; only create the ability to do so. This is why the business improvement opportunities were not presented in numbers but in opportunities for future savings.

1.5 THESIS OUTLINE
Section 1 contains a description of the mission of this thesis project. Section 2 contains a presentation of the company at which this thesis project is conducted. Section 3 contains the theoretical frame-
work that has been guiding this thesis project. Section 4 contains a declaration of how the thesis project has been conducted. It contains a description of what methods have been utilized along with motivations to why these methods were used. Section 5 presents the obtained result. First it presents the result of the mapping of the current state, then the analysis of the current state and finally the result of the concept development.

Section 6 contains a discussion and conclusion of the thesis project. The final and 7th section contains a recommendation to GEHC of how they should proceed with continuous work.

1.6 TERMINOLOGY
The abbreviations in this thesis are presented in table 1.

Table 1. A list of abbreviations that is used throughout this thesis.

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>GE</td>
<td>General Electric</td>
</tr>
<tr>
<td>GEHC</td>
<td>General Electric Healthcare</td>
</tr>
<tr>
<td>ME</td>
<td>Manufacturing Engineer</td>
</tr>
<tr>
<td>BTL</td>
<td>Business Team Leader</td>
</tr>
<tr>
<td>NCR</td>
<td>Non-Conforming Report</td>
</tr>
<tr>
<td>PCA</td>
<td>Printed Circuit Assembly</td>
</tr>
<tr>
<td>LSS</td>
<td>Lean Six Sigma</td>
</tr>
<tr>
<td>SPC</td>
<td>Standard Production Cost</td>
</tr>
<tr>
<td>CAM</td>
<td>Configured and Advanced Manufacturing</td>
</tr>
<tr>
<td>LAB</td>
<td>Lab Equipment Manufacturing</td>
</tr>
<tr>
<td>Mfg</td>
<td>Manufacturing</td>
</tr>
<tr>
<td>VSM</td>
<td>Value Stream Mapping</td>
</tr>
<tr>
<td>SM</td>
<td>Stream Mapping</td>
</tr>
<tr>
<td>TIMWOOD</td>
<td>Transportation, Inventory, Motion, Waiting, Over-production, Over-processing, Defects</td>
</tr>
<tr>
<td>WIP</td>
<td>Work In Progress</td>
</tr>
<tr>
<td>CSM</td>
<td>Current State Map</td>
</tr>
<tr>
<td>FSM</td>
<td>Future State Map</td>
</tr>
<tr>
<td>TS</td>
<td>Tool Shop</td>
</tr>
<tr>
<td>COMM-inventory</td>
<td>Common Inventory</td>
</tr>
<tr>
<td>QC</td>
<td>Quality Control</td>
</tr>
<tr>
<td>PQS</td>
<td>Product Quality Specialist</td>
</tr>
<tr>
<td>QE</td>
<td>Quality Engineer</td>
</tr>
<tr>
<td>NNVL</td>
<td>Necessary No Value-Loss</td>
</tr>
<tr>
<td>CA</td>
<td>Cost-Adding</td>
</tr>
<tr>
<td>NCA</td>
<td>Necessary Cost-Adding</td>
</tr>
<tr>
<td>LTR</td>
<td>Labor Track Record</td>
</tr>
<tr>
<td>QA</td>
<td>Quality Assurance</td>
</tr>
<tr>
<td>MW</td>
<td>Mechanical Workshop</td>
</tr>
</tbody>
</table>
2 Company Presentation

The company where this project is conducted at is presented in this chapter. The chapter is divided into three sections, where the first section address some general information that goes for all businesses incorporated in the enterprise. The second section address the vision of GEHC. The third section address specific information about GEHC in Umeå. More information about GEHC in Umeå is presented later in the thesis.

2.1 GENERAL ELECTRIC
GE was founded 1878 by Thomas Edison, the inventor of the light bulb. The company has become an entrant in transportation, finance, energy, health and home, and it employs more than 300 000 persons worldwide. The company has exercised Six Sigma since the early days of the concept, and is often mentioned as one of the largest and most successful Six Sigma-users. Since a few years back the company has started exercising a version of Six Sigma that is inspired by Lean Production, simply called Lean Six Sigma (LSS), which is explained further in 3.1 LEAN SIX SIGMA.

GEHC is one of the companies included in the GE enterprise, and the major GE business in Sweden. GEHC is located in Uppsala, Danderyd and Umeå (GE, 2015).

2.2 GEHC’S VISION
The vision of GEHC follows “GEHC hardware manufacturing site of choice – passionate employee’s providing our customers cutting edge products to save life today and tomorrow” (GEHC, 2015). They have formed four expressions which every GEHC site strives to achieve. These expressions are described below and presented in figure 1. The expressions are highly influenced by LSS.

- **Right the first time** concerns for instance quality, lead times and standard production costs (SPC) in new product introductions.
- **Predictability & Efficiency** means striving for lean and predictable processes, for example through standardized processes.
- **Standardized flexibility** means that the business should develop methods and action plans which they can follow when conditions change.
- **Responsiveness** means that the employees should aspire to act quickly and synchronized when conditions change or when non-conformances occur. The business encourages the employees to be responsive for signals and to respond to customers in a good way (GEHC, 2015).
2.3 GEHC IN UMEÅ

The site in Umeå employs approximately 400 people. They manufacture medical instruments intended for development and mass production of pharmaceuticals, though they are specialized in instruments for protein separation. They offer more than 200 different end products, with approximately 24 main process flows allocated over 6 different assembly divisions (GEHC Umeå, 2015).

The company hierarchy of the site is illustrated in figure 2. Each manufacturing division (CAM 1-3 and LAB 1-3) are assigned one BTL and 1-2 MEs. Each BTL is presented in figure 2, but the MEs are only represented by their department; Manufacturing Engineering.

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**Figure 1.** The four expressions formed by GEHC (GEHC, 2015).

**Figure 2.** Company hierarchy at GEHC Umeå (Ejderhov and Åkerlund, 2015).
3 Theoretical Framework

As described in 2.2 GEHC’S VISION, the company’s vision is right the first time, predictability & efficiency, standardized flexibility and responsiveness. This section contains a further description of these concepts and their origin in LSS. It also contains a description of a method often utilized in Lean Production; Value Stream Mapping (VSM). The reason to why LSS and VSM are included in the theoretical framework is because of the project members’ intention to work towards GEHC’s strategies and organization goals.

3.1 LEAN SIX SIGMA

Bhuiyan and Baghel (2005) mean that LSS is one of the most used hybrid methodology for continuous improvement of manufacturing processes. The writers describe LSS as a hybrid methodology, which is a combination of two or more concepts. LSS is a combination of Lean Production and Six Sigma. The advantage with the combination of two different concepts is that it can facilitate solving problems that would be difficult to solve if the concepts were used separately (Bhuiyan and Baghel, 2005; Goldsby and Martichenko, 2005).

Using LSS makes it possible to manage and solve different problems since the user can choose among different tools (Salah, Rahim and Carretero, 2010). For example, the core of Lean Production is to reduce waste, and the method and tools of bringing the process into statistical control originates from Six Sigma. Using these methods and tools together makes it possible to achieve both cost reduction and quality improvements. Figure 3 presents tools typical for Lean Production, Six Sigma and Lean Six Sigma.

3.1.1 Right the First Time & Muda

A central part of Lean Production is the seven wastes, also known as the seven mudas. Womack and Jones (1996) describe muda as: “Muda. It is the one word of Japanese you really must know. It sounds awful as it rolls of your tongue and it should, because muda means “waste,” specifically any human activity which absorbs resources but creates no value...” (Womack and Jones, 1996, p.15).

George (2010) calls the seven mudas TIMWOOD, which stands for:
- Transportation
- Inventory
- Motion
- Waiting
- Overproduction
- Overprocessing
- Defects

As George (2010) describes, these wastes

![Figure 3. Tools that are typical for Six Sigma, Lean Production and Lean Six Sigma (Salah et al., 2010).](image-url)
creates costs which can be both visible and hidden. He means that in order to reduce these costs the focus needs to be on reducing the seven mudas.

According to George (2010), reduced transportation can be achieved by developing and implementing simpler layouts and production flows. High inventory costs are reduced by lowering the work in progress (WIP). That is achieved with lower batch sizes and less inventory. It is also important to minimize the motion of people (George, 2010; Womack and Jones, 1996). To walk from one location to another can take a lot of time, which could be spent on more important and value-adding activities. Waiting time is also a waste that should be reduced, since it is not something the customer is willing to pay for. George (2010) describes that both overproduction and overprocessing needs to be minimized, since it involves work that the customer does not want to pay for. Finally, the last one of the seven wastes is work induced by repa-rations, scrap and rework. This is where the connection to right the first time comes in. George describes the waste of defects as: “...defects are likely built into your process due to faulty equipment, instructions, design or, beliefs.” (George, 2010, p.36)

By analyzing processes using tools like value stream mapping, the seven mudas can be reduced and the process will get faster and more cost efficient (George, 2010).

3.1.2 Predictability & Efficiency
Goldsby and Martichenko (2005) describe predictability as in a predictable process, as a result of standardized processes. In order to make a process predictable the writers stress the importance of visualization. With a visible process the defects become more apparent, which enables process improvements. Goldsby and Martichenko (2005) also stress the importance of planning in order to make the process efficient. A process map makes it easy to know the next step of the operation which prevents waste of both time and work.

3.1.3 Standardized Flexibility
With a standardized and flexible work, the process can be predictable, efficient and easy to change when required (Goldsby and Martichenko, 2005). The writers argue that it is difficult to recognize when a process is out of control without a standard. The process also needs to be respondent of changes in order to be flexible. Goldsby and Martichenko (2005) mean that in order to achieve a standardized and flexible process, it is necessary to find the best practice of the process and then to visualize and implement it.

3.2 VALUE STREAM MAPPING
Breyfogle (2003) describes Value Stream Mapping as a tool that is used to discover where effort should be directed in order to improve a business. VSM is a well-recognized tool in Lean Production (Bellgran and Säfsten, 2005: Braglia, Carmignani and Zammori, 2006). The tool is as a simple paper-and-pencil-based technique that helps a company to map and later improve a production process regarding both material and information flow (Chen, Li and Shady, 2010). When using this tool there are a few steps to go through before the improvement work can begin, see figure 4.
3.2.1 Current State Map

When establishing a process map of the current state, the first step according to Bellgran and Säfsten (2005) is to determine which level of detail the process map should cover. Process maps can for instance cover a sub-process, a whole factory, several factories or the process between different companies.

When the level of detail is determined, a map of the current state (CSM) can be established (Bellgran and Säfsten, 2005; Breyfogle, 2003). The CSM is based on collected data and information of the current state. The information required to establish a process map can be gathered by observing the process in progress (Chen et al., 2010). The observation can be conducted by a walkthrough. Depending on what information is required, the walkthrough can be performed downstream or upstream of the material/information flow.

When creating the process map, Braglia et al. (2006) recommends using the symbols in figure 5. However, Breyfogle (2003) recommends some slightly more basic symbols. These are described below and visualized in figure 6.

- Terminal: Defines the start and the end of the flowchart.
- Activity symbol: Contains a description of an element in the process. This symbol has the shape of a blue rectangle on the map.
- Decision symbol: Contains a question following an activity symbol, and offers at least two possible labeled paths, one for each answer. This symbol has the shape of a yellow rhomb on the map.

![Figure 5. Recommended symbol (Braglia et al., 2006).](image)

Figure 4. Steps for the VSM-configuration (Bellgran and Säfsten, 2005).
As Braglia et al. (2006) describe, the manufacturing process-box is often used for activities such as welding or assembling. The data boxes can be filled with various data from the activities, depending on which information is important. The Braglia et al. (2006) stress the importance of using these symbols as a standard. However, Bellgran and Säfsten (2005) only stress the importance of understanding the meaning of the symbols.

The last thing included in the process map is the timeline below the activities, which contains the lead time of each activity and how many operators they require (Bellgran and Säfsten, 2005; Breyfogle, 2003). The lead times can be value-adding, non-value-adding or necessary non-value-adding. When the lead times are established and categorized, their difference can be calculated. The calculation describes the amount of value-adding activities compared to the amount of non-value-adding activities in the whole process. Figure 7 illustrates an example of a VSM.

### 3.2.2 Future State Map

Once the CSM is established the analyze phase can begin. This phase can be conducted by developing a future state map.
(FSM), which will show an ideal state of the process (Braglia et al., 2006; Chen et al., 2010). The FSM can be used as a guide towards the project’s goal and to future lean activities. Breyfogle (2003) recommends that when creating the FSM, the practitioner should keep in mind some lean principles, such as minimal waste, no overproduction, etc. See the seven wastes described in 3.1.1 Right the First Time & Muda.

3.2.3 Advantages and Disadvantages of VSM
Both Bellgran et al. (2005) and Braglia et al. (2006) have described some advantages and disadvantages of VSM. The writers mean that the advantage of using VSM is that the tool displays both material and information flow through the process. The established flows allow future comparisons between different internal processes. The writers mean that using the VSM tool creates good conditions for accomplishing an implementation of Lean Production.

Bellgran et al. (2005) and Braglia et al. (2006) mean that the disadvantage of VSM is the difficulty to exercise the tool on complex processes with multiple flows where products or information can take different paths through the process. This is very common in processes with low volume and high variance. The writers also mean that there is a risk for missing important information if using only VSM. This can be prevented by backing up the analysis with additional tools.

3.3 SUMMARY AND REFLECTION
As the writers describe; performing a project with the ambition to follow the methodology of LSS offers the opportunity to combine two kinds of tool libraries. This facilitates solving problems that would be difficult to solve with only one library of tools to use (Bhuiyan and Baghel, 2005; Goldsby and Martichenko, 2005; Salah et al., 2010).

When the focus lies on reducing rework, it is appropriate to find out which kind of rework that should be approached first. This can be achieved by developing a standard process for rework. Measure and controlling tools from Six Sigma can then be used for improvements of rework.

The methodology of LSS does also include working a lot with visualization. This can be useful when conducting a project that concerns process development. As the writers described earlier, visualization can be obtained with the use of the lean tools Process Mapping and VSM. Process Mapping and VSM do not only contain mapping of the current state but also the development of a future state. This is useful when developing and improving processes. The disadvantage of VSM is the difficulty to apply the tool on processes where the lead times of its activities vary a lot. Therefore is VSM appropriate when the process is non-complex. However, VSM can be useful for more complex processes too, if the tool is combined with other analyzes.
4 Method

This section describes how this project has been planned and conducted. It also describes why this certain way of conducting the project was chosen. The section includes a description of the utilized methods, along with a justification of how and when it was used.

4.1 PROJECT PLANNING

The first activity in the master thesis work was to create a plan for the project. This plan has guided the project members, stakeholders and supervisors towards the defined goal. The project plan contains a description of the company, the project scope and the planned line of action. The time schedule is presented in form of a Gantt chart in appendix 1.

4.2 PROCESS AND CONCEPTUAL PLANNING

The process that was used during this master thesis work was developed by the project members based on the project objectives, with inspiration from Cleland (1994) and his process for conceptual planning.

Cleland (1994) describes conceptual planning as a sufficient framework for achieving a successful project, since the framework supports the organizational goal and mission. This is why the organizations Commitment to a Future Direction have the highest level in the conceptual planning hierarchy. Below this level the Mission and Purpose Statement is placed. Underneath the Mission and Purpose Statement there is the sub-targets called objectives, which have another sublevel called strategies. The strategies should be chosen to accomplish the objectives (Cleland, 1994).

Figure 8 shows a remodeled template for Cleland’s conceptual planning modified for this project. The specific process tree designed for this project is presented in appendix 2. The purpose and objective of this thesis project is the mission and pur-

![Figure 8. Remodeled template with inspiration of Cleland's process tree (Ejderhov and Åkerlund, 2015).]
pose statement in the process tree.

The project was divided into four different phases visualized in the tree. The phases comprise expedient tools to achieve the objective for each phase. These tools will be described later in this section. Since the process tree offers a foreseeable picture of what each phase should achieve and hence what it should comprise, it was a suitable method to use.

4.3 PHASE 1 - DETERMINING THE CURRENT STATE

This phase was the first in the project process and contained three underlying stages called Mapping of the Current State, Compilation and Analysis. Their congruent purpose was to determine the current state of the rework process. Further in this section a detailed description of each stage is presented.

4.3.1 Mapping

In the first stage of Phase 1, the main purpose was to understand and document the current state of the rework process. This required utilization of different methods for gathering information.

4.3.1.1 Interviews

Karlsson, Osvalder and Rose (2008) mean that interviews are appropriate for both quantitative and qualitative information, but that it could require a lot of time and resources conducting them in larger scale. However, they argue that it is an effective method to gather information that perhaps otherwise would remain unknown. Suzuki, Ahluwalia, Arora and Mattis (2007) agree and add that the interviews also reveal the participants words.

This project required both quantitative and qualitative information, but the available time and resources were limited. Interviews were therefore conducted in smaller scale, with two main objectives. First, to gather qualitative information that would help the project members to understand and become familiar with the rework process. Second, in order to obtain information that would make it possible to design a sufficient survey. The survey is described further in the following chapter. The subject of the interviews was the respondents’ definition of rework. The questions concerned which rework activities were performed at each department, how other departments could be involved and how they cooperated around rework.

It was decided to perform semi-structured interviews since Karlsson et al. (2008) mean that it is an appropriate method when the acquired information is both qualitative and quantitative. In line with what the writers recommend, the interviews were carefully constructed to reassure that the questions were relevant to the subject of matter. Karlsson et al. also recommend that the initializing questions should be easy to answer, and familiar to the interviewee. The questions should have a logical order and end with a summary of what has been said during the interview, which allows the interviewee to reflect on how he or she apprehended the questions. Suzuki et al. (2007) express similar advice; initializing questions that “breaks the ice”, leading to specific questions, leading to closing questions where the respondent is offered the opportunity to add information, leading to an explanation of the next step in the process and finally expression of thanks for the respondents participation. Both Karlsson et
al. and Suzuki et al. emphasize that the interviewer must be careful not to fill in words, to rush the interviewee or to influence him or her with their own opinions. Suzuki et al. also stress the importance of refraining interpretation of the respondent’s answers during the interview. This advice was followed when constructing and conducting the interview.

Since interviews are a time-consuming method, a carefully chosen group of people was invited to participate. These persons were chosen in order to create a representation of the whole company. At least one person from each division was interviewed, where they had different positions. The divisions were CAM1, CAM2, CAM3, LAB1, LAB2, LAB3, QC, Advanced Machining, Tool Shop (TS), COMM-inventory, PCA, PQS, QE and the NCR-coordinator. When these people had been interviewed, a few additional persons were contacted for some supplementary questions. A total of 21 persons were interviewed with an age span of 25-60. Two of these were women. The low number of participating women is due to the fact that a lot of the divisions have no or very few women.

The interviews were limited to 30 minutes at the most in order to enable participation for as many employees as possible. The interviews were conducted with one or two persons at a time. Some of the interviews were conducted in a room separate from the production and some at their workplace. The interviews were documented by taking notes.

The importance of informing the interviewee of specific facts about the interview is stressed by Karlsson et al. (2008). This is why the interviewees were informed of the estimated duration of the interviews, its subject, how the answers were going to be documented, how the answers would be used and when the interviewee would be able to take part of the results.

4.3.1.2 Observations

Observations are appropriate when information of how people behave in different situations is desired (Karlsson et al., 2008). The method can reveal knowledge that the observed people are unaware of, and thus perhaps would not appear in interviews. Observations were conducted in this project in order to cover this possible gap of information.

Direct observations are by Karlsson et al. (2008) described as when the observer studies the designated matter with his or her own eyes. A couple of direct observations of actual rework in the factory were conducted by the project members. They observed how the non-conforming material was processed, step by step from detection of non-conformance to corrected item. Karlsson et al. (2008) stress the importance of being discrete while conducting a direct observation, and being careful so the observer does not influence the situation. However, Suzuki et al. (2007) consider observations as a form of interview, and hence give the same recommendations for conduction of both these methods. These recommendations are already described in 4.3.1.1 Interviews, and they do not advocate discretion. The project members chose to ask unprepared questions during the observation in order to better understand the process and to
better understand the actions and decisions of the observed people. They valued this knowledge greater than the possible disturbance of the regular rework process.

Karlsson et al. (2008) mean that some of the disadvantages with observations are that it does not provide knowledge of root-causes to a certain behavior, which means that the result of the observation in some cases can be difficult to analyze. This did not become an issue for the project members since the objective of the observations was not to collect data to analyze. It was rather to become familiar with the rework process, the instruments and modules in the production and to the parlance in the factory.

4.3.1.3 Surveys
Surveys are appropriate to use when data needs to be gathered from a large group of people under a short amount of time, when the data ought to be quantitative or to validate results from previous interviews (Karlsson et al., 2008). Suzuki et al. (2007) promote the same advantages. The surveys conveyed in this project had two objectives. The first objective was to collect quantitative information of the rework process that could be analyzed later. The second objective was to confirm the obtained results from the interviews. These results were also used in order to develop profitable surveys.

Karlsson et al. (2008) write that it requires skills and experience to develop a good survey. This is why the project members chose to put a lot of focus on the development of the surveys. In line with what the writers recommend, they strove after easy and straight forward formulated questions with only one possible interpretation. Check questions and scales were used in order to make it easy for the respondent to answer and to enable statistical analysis. However, the project members decided to create two different surveys, which can be studied in appendix 3 and 4. The second kind of survey contained not only check questions, but open questions too.

The first survey was devoted to the approximately 250 blue collar workers and contained seven simple check questions. The reason for using only seven check questions was to increase the chance of achieving a higher frequency of answers. It was also to focus on quantitative data from the blue collar workers. The survey concerned questions about which department the respondent belonged to, what activities the respondent classified as rework, which activities were time registered as rework, and if there were any differences in how the rework was carried out in the department.

The second survey was devoted to the approximately 90 white collar workers. It contained some of the simple check questions from the survey for the blue collar workers, but also some open questions where the respondent was encouraged to write their own answers. These questions concerned for instance improvement opportunities of the rework process, and how a future rework system could be designed. The survey contained a total of 11 questions. The reasons to why the open questions were added were to obtain qualitative data, and suggestions on design of future rework processes.

In line with what Karlsson et al. (2008)
suggest, both of the surveys were carefully tested and validated in two turns by manufacturing engineers and business team leaders before it was distributed in the factory. The surveys were amended after each test before it was sent to the next test or to final approval. This was conducted in order to reduce the risk of misunderstanding questions, which is a risk emphasized by both Karlsson et al. (2008) and Suzuki et al. (2007).

Lack of participation is another risk pointed out by Karlsson et al. (2008). They mean that the result is not representative for the target group if the fall off is larger than 50%, and that an analysis of the fall off is necessary in that case. The project members put a lot of effort on prohibiting this risk, both through the design of the survey and through its execution. As mentioned before, the survey contained a limited number of easy questions, which took approximately 5-10 minutes to accomplish. The use of encouraging pictures and a “clean” design was supposed make the survey appear fun and simple to fill out. A cover letter described who were behind the survey, its objective and some other brief facts about the survey. The cover letter also described that the respondents had the opportunity to win a lunch at the factory restaurant if they answered and returned the survey within four days. A reminder of partaking in the survey was shown on the local TV screens at the cafeterias during these four days.

The surveys were handed out in paper by the leader at each division, who also collected the answered surveys. The benefit of using this kind of distribution is that it is time-effective. Every survey could be distributed in one day. Its disadvantage is that the project members had to rely on each leader to be encouraging to fulfilling the surveys. However, the project members assumed that the carefully developed surveys compensated their absence.

4.3.2 Compilation

Once the interviews, the observations and the surveys were conducted, the project members could start compiling the gathered information. That process is described further in this section.

4.3.2.1 Data Compilation
When the surveys were collected they were compiled in Microsoft Excel. The quantitative data was utilized to create different diagrams, and the qualitative data was categorized in groups. The groups were formed depending on its subject to make the data more comprehensible. These diagrams and groups were created in order to facilitate later analysis.

4.3.2.2 Process Mapping
Breyfogle (2003) means that process flowcharts can be useful for several reasons, for example they can help reveal opportunities for improvement or when educating staff. Platkus (2014) agrees and means that it also is a sufficient method for identifying opportunities of improvements. This is why a process map was developed in this project, except that the map not only was supposed to “educate” the staff but the whole company. The rework process was not transparent to anyone before this project was initiated.
The symbols described by Breyfogle (2003) and some of the symbols described by Braglia et al. (2006) were utilized when developing the process map of rework. See 3.2.1 Current State Map for description of these symbols.

According to Breyfogle (2003), the flowcharts are usually directed from top to bottom or from left to right, and return loops often directed left and then up. The project members strove to follow this system when creating the rework process map. However, the process proved to be very complicated, which implicated that it was difficult to draw a simple picture of the process.

The process map of rework was created with Adobe Illustrator based on the interviews and the observations. The first draft was then discussed with MEs, BTLs and other relevant personnel, after which it was amended. Further discussions with subsequent amending were conducted in several turns until the process map corresponded with the current state of the rework process. A final discussion was then held with MEs and BTLs to verify that the process map was correct.

### 4.3.3 Analysis

The methods and approaches used when analyzing the gathered data is described in this section. Some of the methods are only inspired by recognized methods and adapted to fit the preconditions of this project. The cause of these actions is also explained in this section.

#### 4.3.3.1 Stream Mapping

Using the conventional method of VSM, the user arranges activities into three different categories in order to eliminate waste. It is a sufficient method in order to simplify process flows, see further description of the method in 3.2 VALUE STREAM MAPPING. The method had to be adjusted from its original function in this project, which is why the project members chose to call it a “Stream Mapping” instead. The adjustments and their motives are described next.

The problem with applying the method on this rework project is that rework is waste. Using VSM, the whole process of rework would probably be categorized as “non-value-adding” and preferable eliminated in order to reduce waste. However, that is not a realistic action for the company today and not the purpose of this project. But because of the method’s effectiveness and because it is well-recognized, the project members decided to adjust the method to fit an analyze of the rework. The adjustment consists of relabeling the categories as in table 2.
Another issue is that the value calculations in VSM are based on time. First of all, the activities in the rework process at the company were not timed. It would require an unreasonable amount of time and resources to collect this data. Second of all, the duration of the activities differs a lot between cases. These are the reasons to why the project members chose to adjust how the value streaming is calculated. Instead of basing the calculations on time, they are based on the share of activities in each category. The goal is to end up with as few activities in the process map as possible. The share of activities in each category was calculated as following:

\[
\frac{\text{Number of activities in NNVL}}{\text{Total number of activities}} \times 100 \% \quad (1)
\]

\[
\frac{\text{Number of activities in CA}}{\text{Total number of activities}} \times 100 \% \quad (2)
\]

\[
\frac{\text{Number of activities in NCA}}{\text{Total number of activities}} \times 100 \% \quad (3)
\]

The activities in the green area of the process map represent the production flow without rework. These activities were not analyzed in the Stream Mapping since improving the ordinary process without rework is outside the scope.

### 4.3.3.2 Data Analysis

When performing the data analysis, data was extracted from the Excel-document containing the answers from the survey. Diagrams were created in order to visualize to what extent the respondents performed certain activities, to what extent they considered these activities as rework, and much more. The objective of visualizing this data was to analyze the current state of the rework process and to find opportunities of improvement.

The main issues detected during these analyses were summarized into a list. The subsequent improvement work was based on this list among a few other aspects.

### 4.4 PHASE 2 - IMPROVEMENT WORK

This phase contained development of a few concepts that became potential future processes of rework. The development was conducted together with employees at GEHC and based on the mapping and analysis of the current state.

#### 4.4.1 Focus Groups

The first method used in the improvement phase was Focus Groups. In line with what Karlsson, Osvalder and Rose (2008) recommend, the focus groups consisted of eight and six participants with one moderator who lead the discussions while the other project member took notes. Two different focus groups were convened. They had different themes and objectives, which is why they were conducted a bit differently from each other. However, the main purpose of the focus
groups was to achieve another perspective on the subjects, intercept new ideas and to validate earlier results.

4.4.1.1 Focus Group 1
The topic of focus group 1 was the rework process. It had eight participants and lasted for three hours, including two breaks where refreshments were served. The meeting was held in a teaching room at the site. Eight chairs with accompanying tables were placed in a U-formation in the middle of the room. The meeting was initiated with a presentation of the thesis project and its members, an explanation of the objective of the focus group and the agenda of the meeting. Kvale (1996) recommends conducting a warm-up exercise before commencing any discussions, which is why the participants were told to introduce themselves and name their workstation. The meeting was divided into three different parts;
1. Discussion about the definition of rework
2. Analyzing and rebuilding the rework process map
3. Summarizing discussion of the rework process.

The discussion about the definition of rework was based on the following questions:
- What is rework?
- When does rework occur?
- By who and how is rework conducted?
- Describe what rework is with one or a few sentences.

The participants were also introduced to parts of the result of the surveys, which was a diagram of which activities were considered as rework. The moderator encouraged the participants to discuss the result. In the meanwhile the other project member wrote down key points of the discussion on a white board visible for everyone in the room.

The second part of focus group 1 was not a conventional discussion, but rather a workshop. The participants were presented to the current rework process map created by the project members. The group was then split into two separate groups, which both were assigned the same task. They were told to perform an SM of the rework activities. It was the same categorization as the project members themselves performed earlier and is described in 4.3.3.1 Stream Mapping. The purpose of this task was not only to obtain an alternative perspective of the categorization. It was also a way for the participants to get a deeper understanding of how the activities in the process map cooperates. That way it would be easier for them to adopt the next task, which was to develop a new, optimal process of rework.

Both groups were assigned material that would facilitate and encourage their tasks. This material can be seen in figure 9. Each cut-out piece corresponds to the activities in the current rework process map. The blue pieces are called “activity pieces”, the yellow pieces are called “decision pieces” and the smaller, white pieces are called “communication pieces”. Each group was also assigned pieces without labeling in case they wanted to create new activities or decisions. Besides the cut-out pieces, they also received a
sheet with the available categories printed, which can be seen in appendix 5.

The third and last part of focus group 1 was a summarizing discussion of the process of rework. It was conducted in the same way as the first discussion of the focus group, but with the following questions:

- What problems could we encounter?
- What is required for you to follow these process flows?
- What information is required to achieve transparent rework?
- What is required for you to log rework?

4.4.1.2 Focus Group 2

The topic of focus group 2 was logging of rework. It had six participants and lasted for two hours including one break where refreshments were served. The meeting was held in a conference room at the site where the participants sat together around a table. Just like when conducting focus group 1, the meeting was initiated with a presentation of the thesis project and its members. An explanation of the objective of the focus group and the agenda of the meeting was also presented.

Focus group 2 was divided into three different parts as well, though different from focus group 1:

1. “The Superheroes”
2. Brain writing
3. Discussion.

“The Superheroes” was used as a warm-up exercise for the participants, just like Kvale (1996) recommends. The project members stressed that no criticism was allowed during this exercise, and they encouraged unrealistic ideas. First, the participants were assigned one superhero or famous person each. The available characters were Pippi Longstocking, Batman, Hermione, Bill Gates, Karlsson-on-the-roof, Robin Hood and Gyro Gearloose. Then they were told to draw or write how they thought that their character would log rework. They had four minutes before they traded characters with each other. Four trades with following drawing time were conducted before the group presented their ideas.

The second part of focus group 2 was brain writing. Once again, the project members stressed that no criticism was allowed during this exercise. The participants were each assigned one sheet with three sections marked “Concept 1”, “Concept 2” and “Concept 3”. The assignment was to draw or write three concepts on how they would like to log rework. They had four minutes to draw before they had to send their sheet clockwise to the person next to them. Consequently, they received a new sheet from the person on the other side of them. They were now supposed to continue on previous person’s concepts. They could either continue developing that concept or get inspired by it and
The third part of focus group 2 was a concluding discussion about how to log rework. The questions discussed were:

- What defines a poorly functioning versus well-functioning system?
- What is required for you to log rework?
- What problems could we encounter?
- What information is required to achieve transparent rework?

The focus groups were not performed strictly as Karlsson et al. (2008) describe the method. The reason to why the project members decided to add a workshop and the above described creative methods (“The Superheroes” and brain writing) to the focus groups was in order to encourage discussions of issues that perhaps were not foreseen. It was also to intercept ideas of how a rework process could be designed and how to log rework. However, the writers’ recommendations were followed during the discussions.

Karlsson et al. (2008) mean that the strength of focus groups is that it makes it possible for the participants to associate and respond to each other’s experiences, which provides a broad range of perspective. Kvale (1996) agrees and adds that it also is a sufficient way for the participants to correct each other, which decreases the risk of obtaining extreme views that are not socially shared. This is why the project members put a lot of effort to invite employees from different divisions, positions, experience, age and gender. They also strove for inviting employees that would not mind sharing their opinion but at the same time would not overpower the other participants. However, Karlsson et al. (2008) mean that there is a risk with these kinds of groups, since they are fictitious and perhaps normally would not come together. The project members chose to disregard this risk because of the possibilities of obtaining new perspective and ideas.

4.4.2 Definition of Rework

The definition of rework was established mainly based on the interviews, the surveys and the focus groups. Comments from the interviews on how the participants defined rework were summarized. The survey questions regarding definition of rework were also summarized. These summaries were compared with the result from the focus groups, where the definition was thoroughly discussed. Based on these comparisons, a definition of rework was formulated. Finally, this definition was discussed and amended together with a selection of managers and the internal supervisor at the site. When these discussions and following amendment was conducted, the definition of rework could be established.

4.4.3 Requirement Specification

The development of the requirement specification actually began in Phase 1 in the analysis of the current state. However, it was not until after the definition of rework was established that the specification could be established too. Hence, the development of the specification was conducted parallel with the work described earlier.

The projects aim and objectives were analyzed in order to formulate requirements
that would help fulfill the aim and objectives. Some of the requirements were derived from the seven wastes. These are described in 3.1.1 Right the First Time & Muda. The project members discussed how a rework process would have to be designed in order to avoid these wastes, and wrote those suggestions down.

The project members also investigated conducted surveys and interviews and wrote down comments and suggestions that would fit a requirement specification of the rework process. The results of the focus groups were also analyzed in order to find requirements expressed by the participants.

4.4.4 Creative Methods
When developing new concepts the project members used a couple of creative methods. First of all, they compiled the result of the focus groups regarding new concepts on a large board. They tried to group the different ideas, combine them and find blanks in order to come up with new ideas. At the same time they discussed advantages and disadvantages with the different combinations and ideas. The project members were the only participants and the documentation was performed through drawings and short written notes.

The project members also conducted a version of brain storming. Much like when performing Brain Storm (Karlsson, Osvalder and Rose, 2008), the project members wrote down every suggestion without contemplating or criticizing its signification. The refining was not supposed to be pursued until the second part of the development, so the project members kept an open mind during this stage.

The advantage of performing such a non-criticizing development is that it decreases the risk of missing convenient ideas.

4.4.5 Selection Method
When selecting which concept to continue develop, the advantages and disadvantages of each concept were listed and compared. Each concept was also compared with the requirement specification to ensure that the most vital requirements were fulfilled. However, the comparison of the advantages and disadvantages was the method that had the greatest influence on which concept to select.

4.5 PHASE 3 - TESTING
The third phase Testing contained further development and validation of the selected concept. This phase was iterated with parts of Phase 2 Improvement Work in order to obtain a sufficient and validated process.

4.5.1 The Prototype
The testing was conducted with a prototype of a system for filing NCRs, created in Microsoft Excel. The prototype only contained the required functions for the concept; its appearance and design was not considered relevant for the testing. This is because it was only the functions that was up for testing, not its appearance.

The prototype was created based on a fictitious database. Writing information in designated cells derived more information from the database, which was one of the prototype functions. The prototype also contained scrollbars where the user had to choose among a few alternatives.
Finally, it had room for a problem description. The inserted information was shown on the next worksheet in the Excel workbook, which was targeted for the receiver. This sheet had a few other functions. A further description of the prototype is presented in 5.4 FINAL CONCEPT.

4.5.2 Validation
Using the prototype described above a testing process was conducted in order to validate the chosen concept. For every test, one ME and one assembler from the same division were invited to test and discuss the prototype and concept. During these meetings, the project members presented the concept and let the participants use the prototype. Following discussions led to further improvements of the concept. Representatives from every division were invited to participate one division at a time.

4.6 PHASE 4 - RECOMMENDATION
The final result of the project was a recommendation of a sufficient rework process. This recommendation was developed in Phase 4, and was based on all previous work during the project.

The recommendation was split into two different parts; one part consisted of a recommendation suitable for instant implementation, and the second part consisted of a recommendation for a future state.
5 Results
This section contains the obtained results that are relevant for the aim and objective of this project. At first, the result of the data collection is presented. This is followed by an analysis of these results, which leads to the requirement specification. Then the result of the concept development is presented, which is a brief description of three concepts. A selection analysis of these concepts is then presented, followed by a more detailed description of the chosen concept. The benefits and costs of the chosen concept are then discussed. Finally, the project issues are answered.

5.1 MAPPING OF THE CURRENT STATE
As the heading announces, this section contains a presentation of the obtained result and following analysis regarding the current state. This analysis leads to the development of potential future concepts, which are described later in 5.3 CONCEPT DEVELOPMENT.

5.1.1 Interviews and Observations
This section presents both the result of the interviews and the observation. The observation revealed that the process of rework is improvised and does not follow any strict standard. There were a lot of deliberations and consulting with different functions before any decision was made. The specific circumstances of the observed case were decisive. In addition, when the outcome turned out to differ from expected, some of the involved parties had to conduct some extra work. That is because they had tried to take shortcuts in the beginning in order to speed up the process.

The answers from the interviews are categorized by the questions. In order to keep the interviewees anonymous, only their position is revealed.

Definition of rework
The interviewees’ answers on what they define as rework are listed below:

- When a non-conformance occurs
- Non-conformances that have to go through the NCR-process
- Non-conformances that can be rectified by either an assembler or by TS
- All time that the MEs spend on support concerning rework
- Every action that is in addition to what is described in assembly instructions and other associated documents
- Troubleshooting
- Retests

Description of process flow for rework
The common denominator among the interviewees’ answers was that the process flow for rework is not consistent. For instance, one of the interviewees stated that when the assembler detects a non-conformance, he or she should always file an NCR. However, that is not the case in the reality according to the interviewee. He said that smaller non-conformances almost never result in an NCR.

All interviewees said that when the assembler is uncertain of what action is appropriate, he or she calls for the ME of that division. The ME investigates the
situation and determines course of action. This could either be scrapping the item, returning it to the supplier, repairing it or filing an NCR. One of the interviewee said that the ME also could decide that the non-conforming material could be “use as is”, which means that the item does not need to be modified in order to function. The interviewee said that a concession report should be filed in this situation, which is also not always done.

When filing an NCR, the interviewees said that the report is sent to the NCR-coordinator who investigates price and non-conformance statistics of the item in question. The coordinator then recommends a course of action based on this information and returns the NCR to the ME who takes action.

Most of the interviewees claim that the assemblers sometimes transport the non-conforming material to the operators at TS for reparation, and sometimes repair the non-conforming material at his or her workstation. One of the interviewees said that the course of action depends on how severe the non-conformance is and the experience of the assembler, amongst other things.

**Which parties are involved in rework and when? All assemblers or one designated?**

One of the BTLs said that the BTLs are informed when non-conformances occur, but that they seldom are required to be involved in the problem.

All interviewees said that the assembler who detected the non-conformance is the one who along with the ME decides what action to take. The rework is not managed by a designated assembler at the division; everyone is equally qualified. However, the assemblers can ask each other’s advice.

**Estimated time spent on rework**

The interviewees were not agreed on this question. Some of them said that it is difficult or even impossible to say, since the assemblers sometimes forget or defy to clock in and out rework. One of the interviewees estimated that approximately four hours of rework was conducted a week at that division, and about two NCRs were filed a day on that same division. Many of the interviewees agreed that the amount of rework differs a lot both between the divisions and time of year, probably because an increased production rate equals higher frequency of non-conformances.

**Relevant metrics when measuring rework**

Most of the interviewees said that relevant metrics would be accumulated time of rework, and how much time the MEs dedicate to rework.

**Do you have any need of knowing the amount of rework, how it varies, etc? What do you need to know? What do you want to know?**

All of the interviewees said that they would like to know how much rework was conducted, preferably in time. One of the interviewees suggested that knowledge of what item is being modified would be interesting.

**Additional thoughts**

Most of the interviewees said that the company should place greater demands on its suppliers by complaining and returning non-conforming material, instead of modifying it in-house. The reason to why this is not standard action today is
because of the increased delivery times it transpires.

5.1.2 Surveys
A total of 115 completed surveys were collected, of which 83 were blue collars and 32 white collars. There are approximately 250 blue collars and 90 collars working at the factory, and if using these numbers when calculating the response frequency the following result is obtained:

\[
\frac{83}{250} \times 100 \% \approx 33 \% \quad (4)
\]

\[
\frac{32}{90} \times 100 \% \approx 36 \% \quad (5)
\]

Below follows a selection of questions that both surveys contained, along with the result of each question.

Choose those activities regarding rework you usually perform. You may choose several activities.

Choose those activities that you deem as rework. You may choose several activities.

The result from the question is presented in diagram 1. The grey bars represent the answers from the white collars, and the blue bars represent the answers from the blue collars. As one can see, the answers differ quite a lot between the two groups.

Choose those activities regarding rework you usually perform. You may choose several activities.

Choose those activities that you deem as rework. You may choose several activities.

The result from the question is presented in diagram 2. Once again, the grey bars represent the answers from the white collars, and the blue bars represent the answers from the blue collars. As one can see, the answers differ quite a lot between the two groups.

Diagram 1. Comparison between the answers from white collars and blue collars. The question was: “Choose those activities regarding rework you usually perform. You may choose several activities.”
Diagram 2. Comparison between the answers from white collars and blue collars. The question was: “Choose those activities that you deem as rework. You may choose several activities.”

Diagram 3. A unification of the questions above. This diagram visualizes the difference between which activities the respondents state that they conduct and what activities they consider as rework.
collars, and the blue bars represent the answers from the blue collars. Just like in diagram 1 the answers differ quite a lot between the two groups in diagram 2. The result of both questions above is unified and presented in diagram 3. The blue bars represent the question about which activities the respondents consider as rework, and the green bars represent what activities the respondents state that they perform. The diagram visualizes the difference between which activities the respondents state that they conduct and what activities they consider as rework.

Mark the time scale where the limit should lie for when assemblers should check in on another work code.

The result from the question above is presented in diagram 4, diagram 5 and diagram 6. Diagram 4 only presents the white collars’ answers, diagram 5 only the blue collars’ and diagram 6 both groups. 10 minutes was the single most chosen answer among the white collars. Diagram 5 shows that the blue collars are of a different opinion. 10 minutes is the third most often chosen alternative, 1 hour is the most often chosen alternative closely followed by 30 minutes. However, if studying diagram 6 with everyone’s answers, one can see that 10 minutes is the most often chosen alternative after all.

Diagram 4. The amount of time that the assemblers can perform an activity before they should check in on another work code according to the white collars.

Diagram 5. The amount of time that the assemblers can perform an activity before they should check in on another work code according to the blue collars.

Diagram 6. The amount of time that the assemblers can perform an activity before they should check in on another work code according to all respondents.
Below follows a selection of the questions from the white collar survey, along with the result from each question.

*How would you grade the function of the rework process today? Mark on the scale (1=Not at all, 10=Excellent).*

As one can see in diagram 7, the white collars seem to think that the current rework process works badly. The mean score is 2.6 on a scale from 1 to 10.

![Score - Rework Process](image)

Diagram 7. The result from the question "How would you grade the function of the rework process today? Mark on the scale."

Mark the time scale where the limit should lie for when MEs, BTLs, etc. should check in on another work code.

The result from this question is presented in diagram 8. Compared with diagram 4, where the white collars answered the same question but for the assemblers, there are some major differences. According to the white collars; the assemblers should check in a lot earlier than MEs, BTLs, etc.

![Check in for MEs, BTLs, etc: White Collar Prefer](image)

Diagram 8. The amount of time that the MEs, BTLs, etc. can perform an activity before they should check in on another work code according to the white collars.

Do you think that the rework process differs between you and your associates? If that’s the case, how does it differ? The result of this question is presented in the pie chart in diagram 9. Most of the respondents that answered “Other” motivated it with lack of knowledge of how their associates approach rework. Some of the motivations for the yes-answer are presented below (freely translated from Swedish):
“Probably. It differs between cases for me too.”

“Yes. Responsibility for purchased material is passed to PQS without responsibility for production.”

“Yes. A lot of opinions of different approaches and executions.”

How can the rework process be improved?

Some of the answers are presented below (freely translated from Swedish). Many of the respondents stressed the importance of clarifying responsibility. One of the respondents of this opinion wrote the following: “Clarify who’s responsible and for what depending on the nature of the matter. Who pays, who takes action, who do the assemblers turn to?”

A few of the respondents meant that rework should not exist. One of them stated the following: “One should not improve the process; one should assume that it does not exist.”

Many of the respondents meant that the reporting and registration should be simplified. One of the comments was: “Simplification regarding registration and follow-up, perhaps some kind of workflow where all history is stored in the case. This should facilitate when several actors are involved, especially when concessions, regulators and certificates are involved.”

Some of the respondents requested a follow-up on the amount of rework: “We must gain knowledge of what we rework and to what extent we rework.” “Visualize how much time we spend reworking/which production group performs the most rework”.

Some other suggestions were:
“Higher demands on suppliers, improved specifications from design/construction, reclaim non-conforming material more often”

“A team of experts who takes care of all rework on purchased material.”

“The inventory should automatically be checked and if necessary be rectified when discovering a non-conforming item.”

Diagram 9. The result of question 7 in the white collars’ survey. The question read “Do you think that the rework process differs between you and your associates? If that’s the case, how does it differ?”
What measures of rework are interesting to you? (For instance time, frequency, etc)

The respondents answered the questions independently with their own words, meaning that they did not have given response alternatives to choose from. The result is presented in diagram 10.

How should the ideal system for logging of rework be designed according to you? Feel free to draw on the next page!

Almost half of the participants chose to leave this question blank, see diagram 11. 36% of the respondents wrote a description of their suggestion, and four of the respondents chose to draw a picture. A selection of the written suggestions is presented below (freely translated from Swedish).

"It would be ideal if we did the right thing from start, read and assembled according to the instructions in order to avoid reclaims due to assembly errors."

Diagram 10. The result of the question: “What measures of rework are interesting to you? (For instance time, frequency, etc)"

Diagram 11. Result of how the respondents chose to answer the question: “How should the ideal system for logging of rework be designed according to you? Feel free to draw on the next page!”
"Automated, or designated persons that handles rework. ABSOLUTELY no rework in production lines."

"Don’t have a complete solution, but as automated as possible and 'mobile registration'."

“When a non-conformance occurs, the assembler immediately registers 'rework' and scans item number and if necessary serial number in his or her tablet. The assembler retrieves a unique ID which can be used later by others to register rework if the case is escalated. When each person is finished with their part in the rework, they check out from the unique ID and automatically return back to their originate LTR-code." (LTR = labor track record).

“Desirable if one did not have to use several systems! The different operations in the rework process require different sub-systems for registration, for instance LTR/FLEX for time, Lotus Notes for handling NCRs and Concessions, and Oracle for material transactions."

"Scan start + item number, perform the rework, scan finish + item number + likely error cause and what the assembler did"

5.1.3 Process Map
As shown in the established CSM in figure 10, the current state of the process is complicated. It has 44 different activities and decisions, and it is inconsistently followed between cases. The green area in the established CSM represents the ideal way, which means that the item or instrument does not require any rework. The ideal way consists of 14 activities or decisions, which mean that the rest, 75 %, are rework related operations.

The mapping also revealed that there are two different kinds of rework; rework that is caused by non-conformances that occur before the production and non-conformances that occur during the production. Below follows a description of these occurrences.

5.1.3.1 Non-conformances Before the Production
Rework can be caused by non-conformances occurred at the beginning of the process, after the second activity in the CSM; “Order anyway”. This happens when the purchaser decides to order material that the supplier state is non-conforming. The situation can occur if GEHC needs the specific material as soon as possible, but the supplier can only offer non-conforming material at a time due to some production problem. The two parties can then agree that GEHC orders the material and modifies it in-house, but that the supplier is responsible for the modification costs. The decision to order non-conforming material is made together by the purchaser, the supplier, the production and the TS. If so, a concession report has to be filed by an ME and approved by Quality Assurance (QA) before it can be delivered to the terminal, inspected by the ME and modified by TS.
Figure 10. Established process map of the current state (Ejderhov and Åkerlund, 2015).
Rework can also be caused by non-conformances that are discovered by QC at the incoming inspection terminal. These non-conformances are usually due to errors from suppliers or inadequate specifications. QC controls approximately 10% of the incoming material. If the material is detected as non-conforming, the QC will contact the production and the TS to determine if the material should be reclaimed or modified at the TS. Before sending the material to TS, a rework form has to be filed. This form contains information of the non-conformance and how the material should be modified. After the material has been modified, but before the material is transported to the inventory, an NCR may be filed. A further description of the NCR-process is presented in 5.1.3.3 NCR-process.

Finally can non-conformances also occur at the Mechanical Workshop (MW). MW manufactures material in-house which they inspect after the manufacturing. If non-conformances are discovered at this state, they usually just modify the material without any further actions. The modifications are mostly conducted at the MW, but sometimes at the TS.

5.1.3.2 Non-conformances During the Production
As described earlier, approximately 10% of all incoming material from suppliers is inspected at the QC. The rest of the material is put directly into stock. The material is then distributed to the different assembly lines where it is assembled into modules and instruments.

Non-conformances can be discovered or occur at the assembly lines. Some usual non-conformances are: unfitting material, material out of function, test fails or handling errors. Regardless of what kind of non-conformance occurred, the approaches differ a lot between cases. This can be seen in the established CSM in figure 10. The different approaches are usually:
- Scrap material immediately.
- Modify material, either at the assembly line or by TS.
- Further investigation by the assembler or the ME.
- File an NCR.

The NCR-process and filing the NCR is described further in 5.1.3.3 NCR-process and 5.1.3.4 Filing an NCR. The work around non-conformances is sometimes time registered and sometimes not.

When the material is rectified it is either returned to the inventory or returned to the assembly line for further testing or assembling.

5.1.3.3 NCR-process
Filing of NCRs is inconsistent at the factory today. It is filed at different points of the rework process and it is not filed for every non-conformance. The NCR is supposed to be filed by the person who discovers the non-conformance, which most of the times is an assembler. When the assembler discovers a non-conformance, there seems to be three different approaches regarding the NCRs:
- File an NCR right away
- Consult associated ME and then file an NCR
- Neglect to file an NCR

If an NCR is filed, it is sent to the NCR-
coordinator. The coordinator adds information of the non-conforming material’s price and NCR-history. If the description of the problem is inadequate, he may need to contact the founder of that NCR for further information. Based on knowledge of price, NCR-history and problem description, he sends the NCR to the concerned ME along with a recommendation of approach. A summary of usual approaches is listed below.

- Investigate the non-conformance. This often means communication with supplier, purchaser, PQS, BTL, QC or planner.
- Scrap the material.
- Modify the material at the TS.
- Modify the material at the assembly line.
- Use as it is, which implies filing a concession.

The ME retrieves the NCR, performs an investigation and takes action based on that investigation.

5.1.3.4 Filing an NCR
The following description of how to file an NCR can preferably be read while viewing the screen shot of the current NCR-form in appendix 6.

When filing an NCR, one first has to log in on the computer for the group one belongs to and to the NCR software. Then one must choose from a scroll bar who is going to retrieve the NCR, and click the check box for “Notify”. The status has to be changed from “Draft” to “Investigation”. Next, the “Production Information” field has to be filled out.

“Item no” is a combination of multiple digits representing the article number of the item. The “Item name” is the literal notion of the item. “Item no” along with “Item name” can be found on the item or accompanying packaging. The “Product no” and the “Product name” is the parent to the item and can be found on the order document. Much like “Item no” and “Item name”, it is also a multiple digits combination and a literal notion. “Document no” is also a multiple digits combination which can be seen on the order document. “Order no” and “Order Quantity” can be seen on the order document, too. “Product type” is a scroll bar which is to be changed to “Normal”, “ISO13485” or “Medical Device”. “Category” is also a scroll bar. “No of faults” is the number of items found with the same problem. “Serial no” is unique for each item, and can be seen on the item itself or its packaging. However, not every item has a serial number. “Contact Person” and “Prod. Group” is the name of the person filing the NCR and which production group he or she belongs to. Finally, “Problem desc” is where the problem is described with own words. When this is written, the only thing left is to save the NCR, which brings it to the receiver.

To summarize, there is one check box to click, five scroll bars to define, seven multiple digits combinations to write, three different names plus one preferably detailed problem description to write. All of this is written manually.

5.1.3.5 On Call at Tool Shop
TS have a designated person who takes care of incoming rework. A picture on the wall at the TS clarifies who is on call at the moment. This facilitates locating the person on call for MEs, assemblers or whoever delivers the non-conforming material to the TS.
One of the operators at the TS estimated that the person on call dedicates approximately 30-100% of total worktime to rework during a day. Sometimes the assigned rework is too much for one person to handle, which leads to queues. The person on call can then ask for support from another operator at the TS. When no rework is current, the person on call performs regular TS-tasks (regular tasks comprise creating fixtures and tools to the production).

5.1.3.6 Material Restoration
When the non-conforming material has been scrapped, reclaimed or transported to the protected area, the concerned assembler needs replacement material in order to continue assembling. If the material is provided by the two-bin system, the assembler simply retrieves new material by himself or herself. If it is not, the replacement is conducted a bit differently between the divisions. For instance, most of the assemblers at Biacore in CAM 3 have spider authority. This means that they can log on to the company’s inventory management system, book out material and retrieve it from the inventory by themselves. The assemblers at Wave in CAM 3 do not have spider authority, which means that they have to contact their spider in order to obtain replacement material. (Biacore and Wave are the name of two different brands that is assembled by CAM 3).

5.1.4 Focus Groups
The result of the conducted focus groups is presented in this section. The result is divided into 5.1.4.1 Focus Group 1 and 5.1.4.2 Focus Group 2, since they were conducted separately and contained different activities.

Some of the discussed subjects during the focus groups validate the result from 5.1.3 Process Map, meaning that some of the results from the focus groups are a repetition of the content in 5.1.3 Process Map. The project members decided to exclude these repetitions in the thesis report, but to keep them in mind during the analysis.

5.1.4.1 Focus Group 1
The discussion regarding the definition of rework during the first focus group resulted in a few ground points which led to a final definition of rework. This definition is presented in 5.3.1 Definition of Rework. The rest of the discussions were a verification of the information presented in 5.1.3 Process Map.
The second assignment for focus group 1 was to establish a new categorization and corresponding Stream Map. The group was split in half, and each group created their own categorization and map. The result of the categorization is presented in figure 11. The two different categorizations differ a lot between the groups. However, the groups had the same opinion in the categorization of the three activities and decisions; “Terminal”, “Reclaim” and “Scrap?”. These three were all put in the NNVL-box. The “Reclaim”-activity was placed in the NNVL-box because of the considered importance of reclaiming non-conforming material. The groups also considered that the activity does not add any costs since they thought that it is the suppliers’ responsibility to deliver correct material. Hence, it should be the suppliers that pay for the extra charges. The “Terminal”-activity was placed in the NNVL-box since it already exists in the green-marked area of the CSM. The material has to arrive somewhere at the site. At last, the “Scrap?”-decision was placed in the NNVL-box since the actual decision whether to scrap the material or not does not imply any value-loss.

Another similarity between the two groups was the placement of the activities and decisions; “Exemption created by ME”, “Purchase”, “Investigation by ME” and “NCR?”. These were all placed in the NCA-box. Both groups meant that these activities are necessary, but that they are cost-adding too.

One of the major differences between the two groups was the categorization of the “Tool Shop”-activity. The first group placed the activity in the CA-box. The
second group on the other hand, decided to modify the activity. They separated it into two different functions depending on the current circumstances. The activity was placed in the NNVL-box if it is the supplier who takes the whole cost for the rework. However, the activity was placed in the NCA-box if it is GEHC that stands for the rework cost. This modification is marked with a green dot in the corner of the activity in figure 11.
Figure 12. FSM developed by the first group (Ejderhov and Åkerlund, 2015).

Figure 13. FSM developed by the second group (Ejderhov and Åkerlund, 2015).
The result of the two groups FSMs is presented in figure 12 and 13 above. The maps from the two groups are quite alike. Both groups had excluded the purchasers’ possibility to order non-conforming material from the supplier. They also discussed that the company should reclaim all non-conforming material from the supplier, unless it was caused by insufficient specifications and drawings. In this case, it would only be okay for the company to modify non-conforming material in-house if it was caused by insufficient specification drawings.

The result of the third and last question is presented below. The section is divided by the discussion points.

What problems could we encounter?
Once again in this discussion, the NCR was brought up. Improvement of the NCR is considered as vital in order to obtain future improvements of the rework process. The participants require a simpler system for filing NCRs, with fewer sections to fill out and more oriented towards its users. In order to increase the motivation to actually file an NCR, the feedback must be quicker and more frequent to its creator. Hence, it will be difficult to achieve future improvements unless the NCR is improved first.

What is required for you to follow these process flows?
The most important thing in order to follow a new process is the simplicity of the new process flow and the knowledge of what to do and when to do it. But to motivate following the new process the participants require information of the purpose of the changes.

What information is required to achieve transparent rework?
To make the rework transparent, the process or system needs to register the rework even though an NCR is not written. It requires clear directives of when to only register rework and when to file an NCR.

Registering rework is considered as very important, but today’s system only registers the time of the rework. No other information is registered. Which order or article it concerns could be of relevance, which would make the system more valuable. The participants also stressed the importance of registering rework on different accounts, to make the rework more transparent. These accounts should represent the different reasons of rework such as rework caused by handling errors, rework caused by material non-conformances or rework caused by others things.

What is required for you to log rework?
In order to motivate the assemblers to register rework, the most important measure is to simplify the register system, and making it easier to use. Another motivator would be to come up with some kind of reward for those who register rework.

5.1.4.2 Focus Group 2
The participants were a bit retracted in the beginning of “The Superheroes”-exercise. However, as the time passed, they became more and more creative. In the end, the result of the exercise was several, mostly unrealistic ideas. For example, one of the participants came up with an idea on how Batman would regis-
ter rework. Batman would simply use his high-technological equipment for this matter. He would use a gadget on his belt for registering rework every time he performed some rework related tasks. Another example is the Pippi-way of registering rework. Pippi would bring the non-conforming material to a tool shop and retrieve a golden coin in return. This golden coin would be stored somewhere until she was to be rewarded for all the golden coins she had earned.

When “The Superheroes”-exercise was conducted, the participants partook in brain writing. This exercise revealed that many of the participants wanted to remove the non-conforming material from the production lines and bring it to a “rework-unit”. This unit would be specialized at reworking material. The process would begin when an assembler discovers a non-conformance. He or she would then light a red lamp at that workstation for everyone to see. The lightning would automatically send a signal to the rework-unit, which then would arrive to retrieve the material. When the material is removed from the production line the operator can register the time, the order, the material and the non-conformance. This information would then be sent to the rework-unit.

Another result from the brain writing was an idea of simplifying the way how to register time or other measures about the non-conforming material. This would be achieved by assigning tablets to every workstation. The tablet would contain sufficient applications to register rework, viewing documents regarding the assembly, etc.

There was also an idea of locating computer stations at each division, which would only be utilized for registering rework. However, the one idea that all the participants agreed on, was a simplified data system for registering rework. They discussed that it would be ideal if all data-related activities only required usage of one system. This system would include viewing test data, filing NCRs, access to the inventory system, etc. The participants also expressed a need for automatic input in the NCR by for instance a scanner or some other technical equipment.

The third and final task during focus group 2 was a discussion regarding how to log rework. The discussion and its questions are presented below.

What defines a poorly functioning versus well-functioning system?

A well-functioning logging system was described as an easy system without the need for previous knowledge. The system should register information that could be used immediately in order to reduce the frequency of reoccurring non-conformances. The participants stressed the importance of receiving feedback on what approaches have been taken due to their filed NCRs.

A poorly-functioning logging system was described as the opposite of the system described above. Such a system would be both difficult and time consuming for the assemblers.

What is required for you to log rework?

The well-functioning system described above would motivate the assemblers to log rework. The participants also meant that it is important to spread knowledge
about the importance of logging rework and when to log rework. As one of the participants said: “Even the best of logging systems would be useless if it is unclear when to log rework and if the point of logging rework is unknown.”

What problems could we encounter?
One known problem that can occur when implementing a new logging system is a negative attitude amongst the users. This can be avoided with a transparent implementation where the why’s and how’s are communicated. It is also important to involve the users in the implementation in order to make the system work not only in theory but in practice too.

What information is required to achieve transparent rework?
One of the participants suggested defects per system. Two other suggestions were time of rework and the frequency of rework. They also discussed that the registration system should not have input boxes that allows the user to write with their own words. They meant that this would create a large variety in the NCRs, since the users probably will write very diverse descriptions. This variety will counteract the transparency.

5.2 ANALYSIS OF THE CURRENT STATE
Below follows an analysis of the obtained results from the mapping of the current state. The analysis is divided into three sections, starting with analysis of the result of the mapping, then analysis of the compilation result and finally a summary of the detected main issues. The section is ended with a requirement specification.

5.2.1 Mapping Results
The answers from the interviews were quite alike except for one question: “Estimated time spent on rework”. Why this question did not have a common answer is probably due to the overall lack of knowledge on the amount of rework. The respondents made wild guesses instead of relying their answers on some kind of fact. The interviewees were quite agreed on the rest of the questions. This means that these answers probably represent the opinion of many of the employees. The other issues detected during the interviews are listed in the summary of this analysis, presented in 5.2.3 Summary of the Main Issues.

The answers of the surveys are scattered, especially when the answers of the blue collars and the white collars are analyzed together. The answers among the two groups separately were quite similar though. This was expected since the two groups have different positions, assignments and therefore probably different perspectives on the matter. Still, their respective answers are equally interesting and important. The large spreading of the answers is probably a proof of that the process of rework is unclear for most of the respondents.

Some of the questions of the surveys resulted in particularly low response frequency, which is partly why these questions were left out of the result and analysis. It is also due to the fact that the project evolved from its initial state, which resulted in that some of the original questions no longer were relevant. This is discussed further in 6.2 Method.
One of the questions of the survey concerned when the assemblers should register rework. The result of the question is presented in diagram 4, 5 and 6. Diagram 6 presents the overall result of the question. This diagram shows that the majority of the respondents think that rework should be registered after 10 minutes. The respondents answered this question with the current registration system in mind. If the system became much simpler, it would be easier to motivate the employees to register more often. This should be considered while determining when rework should be registered. If also considering the current escalating model where the time limit of registration is 5 minutes, it would be appropriate to determine that all rework should be registered after 10 minutes. All rework that takes less time does not have to be registered. Basing this decision on the shared opinion of the respondents increases the chance of them being satisfied with the decision. This in turn increases the chance to achieve a standardized process of rework. If the limit had been determined to 1 hour, as the second highest opinion was, the amount of unreported rework would be too high. That does not correspond with the project goal of transparent rework.

The surveys also revealed that around 50% of the respondents considered that replacing items, troubleshooting and communication with the ME and the BTL is rework. However, they do not always register these kinds of rework. This is probably due to the occasions where the assembler estimates that the occurred non-conformance requires a minor effort, but then it proves to be far more demanding. Then it may be considered to be too late to check in on the rework-code in the time registration system. Clearer directives and a more standardized process would probably improve this situation.

The observations confirmed the information obtained from the interviews and the two surveys. The recurring issues detected during these three data collection methods are summarized in 5.2.3 Summary of the Main Issues.

5.2.2 Compilation Results

Due to the lack of standards, the process map of the current state proved to be complex. This can be seen in the CSM in figure 10. However, the actual process is apparently even more complex, according to the participants of the validation of the CSM. The complex and unstandardized way of performing rework contributes to a lot of unreported rework. The directives of when and how to register rework differ between the divisions, as were shown in the interviews, the observations and the surveys. It also allows duplicated work, due to the possibility for the assembler, the ME and the NCR-coordinator to start an investigation. Another effect of the unstandardized process of rework is that the assemblers at the different divisions can decide how to approach problems on their own. This entails a risk for misunderstandings, and it complicates cooperation between the divisions. It is also why the CSM have such high number of decision marks. Another risk that the unstandardized process could entail is the risk of large amounts of time paid to discussions with colleagues how to proceed with an occurred non-conformance.
The current system for registering rework actually consists of two systems; one for registering its duration and another for reporting information of the non-conformance. The two systems are utilized in a way that results in unreliable data, meaning that it does not correspond with the reality. This is probably due to the inadequate design of the NCR, but also due to the lack of information of the purpose to why one should file an NCR and register the rework time. It also seems like that feedback on filed NCRs would increase the share of filed NCRs. This is because the assemblers would be able to follow the sequence of events concerning their filed NCR, and receive knowledge of what actions were made. Receiving this feedback would give purpose to the assemblers and motivate them to register rework.

It seems like that a lot of the problems discovered in the current state are somehow related to the registration of rework. It is necessary to standardize the process of rework, standardize when and how rework should be registered, determine who is responsible for specific actions and improve the design of the NCRs. It is also desirable to implement feedback on filed NCRs. These measures would amount to more reliable data regarding rework. The data could then be used to fortify complaints to the suppliers, and to locate improvement opportunities. If higher demands could be put on the suppliers, the share of non-conforming material originating from them could be reduced as well. However, one must not forget one important approach that probably also would decrease the share of reoccurring problems. That is focusing on increasing the share of reclaims, increase the number of root-cause investigations and improve the drawings and specifications. This is because it is not always the suppliers’ fault that GEHC receives “non-conforming” material; sometimes it is the specifications that are inadequate. Hence, the material manufactured according to these specifications become inadequate too.

With the analysis in mind a Stream Map was developed which is presented in figure 14. The four activities and decisions placed in the NNVL-box accounts for 16% of the total amount of activities and decisions. They were considered as rework that would prevent further problems, which is why they were categorized as no value-loss, even though they are rework.
The nine activities and decisions placed in the NCA-box accounts for 48% of the total amount of activities and decisions. They were considered as necessary rework, but rework that should be reduced if possible. This is because they are cost-adding. One example of such an activity is the “NCR?”-decision. It is necessary to document the non-conformances in order to perform improvements, but it should be clear when to file this report. Wondering and investigating when the report should be filed takes unnecessary time, which means that it is only cost-adding.

The activities and decisions that were placed in the CA-box were considered as unnecessary and cost-adding. They account for 36% of the total amount of activities and decisions. One of the activities placed in this box was the “NCR-coordinator”-activity. This is because it seemed like an unnecessary activity to first write the problem description in the NCR, and then send it to the coordinator who assures that the description is adequate and add some information about the item. It would be better if the NCR was adequately filled out in the first place, and that the associated information would be automatically filled in by the program itself. This falls in line with one of the cornerstones of LSS; right the first time.

The “Modify at assembly line”-activity was also placed in the CA-box. This is because modifications at the assembly lines stop regular work. This increases the throughput time and hence the costs too. If the rework could be lifted out of the production lines, the assemblers could continue with regular work. This would only imply extra costs for the rework, and not for increased throughput times. This
approach falls in line with Lean thinking as well.

5.2.3 Summary of the Main Issues
When overlooking the result of the mapping and compilation of the current state, the overall impression of the rework process was that it is complicated and problematic. This is due to the problems discovered during the mapping. These main issues are listed below.

- No standard of how to conduct rework
  - Many choices to make in the process.
  - Many consultations and investigations before a decision/adjustment can be made.
  - No clearly delegated responsibility of the occurred rework
- No standard of when and how to register rework, and a poorly-functioning software for the registration
  - High amount of unreported rework, both minor and major.
  - Unreliable data, which means that it is difficult to confront suppliers or work with improvements.
  - No continuous follow-up or feedback on the result of the NCRs.
- Large amount of the non-conformances are discovered on purchased material

5.2.4 Requirement Specification
The requirement specification is divided into two sections; one for requirements regarding the process of rework and the other for requirements concerning the NCR.

Process

- Fewer decisions or activities and less non-value adding time spent in the rework process.
- The process should be standardized.
- The process should be obvious to everyone at the factory
  - There should always be one person in charge of a rework
- The factory should strive for lifting out the rework from the production lines.
- All manufacturing divisions should have the same determined time limit of when to register non-conformances.
- The registered data of non-conformances should include:
  - Time of rework
  - Higher resolution on the registered data

NCR
- Filing NCRs should take less time with:
  - Fewer data inputs in the software
  - Self-explaining design of the software’s interface
  - Easy access to the required equipment
- The NCR should contain:
  - Contact information to the creator
  - Information about the non-conforming material
  - Information about associated order
  - Description of the non-conformance
  - Number of non-conformances
  - Description of the chosen approach
- The creator or manufacturing division should receive information of the chosen approach.

5.3 CONCEPT DEVELOPMENT
This section contains a presentation of
the established definition of rework and the three concepts developed in this phase. It also contains a selection analysis for which of the concepts to select for further improvement work. Finally, it contains a more detailed description of the selected concept.

5.3.1 Definition of Rework
As a result of the problem description of the current state and together with the participants from the focus groups, a final definition of rework was developed. This definition is presented below.

“GEHC’s definition of rework is all the extra work caused by malfunction or material that differs from their specifications. Rework must be reported in order to achieve a real and transparent picture of rework. It can occur everywhere in the factory and can involve all departments.”

The definition is supposed to permeate the future process of rework. It can also be used as a guideline for when deciding which activities to register as rework.

5.3.2 Concept 1 - NCR Station
One portable NCR station is located at every division. The station contains a laptop, a camera, a scanner and a printer, and is only utilized for matters regarding NCRs. When a non-conformance occurs, the assembler fetches the NCR station to his or her workstation and files an NCR. The assembler selects approach based on the information retrieved in the NCR. The non-conformance is delegated to another part, and the assembler can continue with regular work.

The NCR concept requires one laptop, one camera, one scanner and one printer for each division, along with sufficient software. The station could be built in Cree Form, which is a module material already used in the factory.

5.3.3 Concept 2 - Pool
A pool of assemblers with workshop competence is created, along with a designated area in the factory with sufficient tools and equipment. The pool of assemblers is located at this area. The pool is assigned all rework in the factory, and that is their only assignment. Whenever a non-conformance is discovered in the factory that needs to be modified, it is transported to the pool. The pool rectifies the non-conformance and transports it back to the production. The workers in the pool are the only ones in the factory that registers time for rework.

This concept requires recruiting of competent people to the pool. It also requires investment in sufficient tools and equipment, and liberation of enough space in the factory.

5.3.4 Concept 3 - Advanced
Every work station is assigned one tablet each. This tablet can be utilized for several operations. It can be used for filing NCRs and to check in and out on different work codes in the time register system. It can be used to scan barcodes for identification or to take photographs of specific problems. It can also be used to view documentation such as assembly instructions, drawings, specifications, etc. The internal education programs can also be conducted using the tablets, and it facilitates for the assembler to check their email.
When a non-conformance occurs the assembler files an NCR with the tablet. The assembler selects approach based on the information retrieved in the NCR. The non-conformance is delegated to another part, and the assembler can continue with regular work.

The necessary measures to attain this concept are to purchase one tablet per work station along with sufficient software. It also requires gathering the mentioned documentation on a drive for easy access. This is because the documentation today is stored on a database which requires user credentials in order to get access to its content. Creating more users in the storing system costs money, and to navigate in the system requires some experience.

5.3.5 Selection Analysis
The advantages of concept 1 - NCR Station are the following:
- Faster process for rework.
- Decreases non-value adding work.
- The rework is lifted out of the production.
- Less movement of material and assemblers between work station and location for filing NCRs.
- Simplified NCR.
- Increases the rate of filed NCRs for the occurred non-conformances.
- Enables future improvements due to increased amount of data.
- Standardized work, clearer what to do and when to do it.
- Decreases the risk of performing double investigations of the same problem, since the responsibility of the problem is delegated to one person.

The disadvantages of concept 1 - NCR Station are the following:
- May require some education.
- Initially an increased number of NCRs which takes time.
- Two separate systems for registration of time and filing NCRs.
- Requires change of work method. Resistance of change can be a problem.

The advantages of concept 2 - Pool are the following:
- The rework is lifted out of the production.
- Fewer check ins/check outs for the assemblers.
- Clear where all rework is rectified.

The disadvantages of concept 2 - Pool are the following:
- Expensive investment (hire personnel, purchase equipment, education, etc.).
- Extra charges for maintenance (salaries, machines, etc.).
- Creates resources for rework, which the company aims to decrease.
- Risk for non-occupied machines due to shifting amount of rework
- Requires space in the factory.
- The pool requires highly skilled personnel with excellent product knowledge.
- Requires a very clear description of the problem in the NCRs. Otherwise it will infer a lot of time spent finding the creator of the NCR and questioning that person of the occurred problem.
- Two separate systems for registration of time and filing NCRs.
- Requires change of work method. Resistance of change can be a problem.
- Initially an increased number of
NCRs which takes time.

The advantages of concept 3 - Advanced are the following:
- Faster process for rework.
- Decreases non-value adding work.
- Simplified NCR.
- Increases the rate of filed NCRs for the occurred non-conformances.
- Enables future improvements due to increased amount of data.
- Standardized work, clearer what to do and when to do it.
- The rework is lifted out of the production.
- Decreases the risk of performing double investigations of the same problem, since the responsibility of the problem is delegated to one person.
- Could be utilized for several operations, for instance logging rework, filing NCRs, scanning, etc.
- Less movement of material and assemblers between work station and location for filing NCRs.
- Requires less usage of paper in the factory.
- Facilitates updating documentation.

The disadvantages of concept 3 - Advanced are the following:
- Expensive investment.
- Requires change of work method. Resistance of change can be a problem.
- Initially an increased number of NCRs which takes time.
- May require some education.

Comparing the advantages and disadvantages between the three concepts made it obvious which concept to opt out. Concept 2 - Pool requires a major investment and adds continuous costs. These expenses do not help to decrease the amount of rework; they rather equip the factory to deal with more rework. This goes against one of the company’s goals; to reclaim non-conformances more than before and to decrease the amount of internally rectified rework. In conclusion; to choose concept 2 would be to go around the problem rather than to solve it. That is why concept 2 was opted out.

Both concept 1 and 3 fulfill the requirements specifications. However, the advantages of concept 3 - Advanced outperform the advantages of concept 1 - NCR Station. This is because both concepts have the same advantages, except that concept 3 has three additional advantages:
- Requires less usage of paper in the factory.
- Facilitates updating documentation.
- Could be utilized for several operations, for instance log rework, file NCRs, scans, etc.

The disadvantages between concept 1 and 3 are also very similar, with two differences. Concept 3 requires a major investment in some kind of tablets with sufficient software, and concept 1 still has two separate systems for filing NCRs and time registration. However, concept 1 could be an appropriate milestone in order to achieve the state of concept 3. This is because concept 1 does not stand in contradiction to concept 3. Most of the changes required for concept 1 would still be sufficient for concept 3.

Since concept 1 requires less investment than concept 3, but is an appropriate milestone towards concept 3, the selected concept is number 1 - NCR Station.
5.4 FINAL CONCEPT

Concept 1 - NCR Station is briefly described in 5.3.2 Concept 1 - NCR Station. This section contains a more detailed description of the concept and an instruction video for how the Final Concept works at the site, see http://youtu.be/hfRnp_rKW50. The process flow for the concept is visualized in figure 15. The process starts when an assembler discovers a non-conformance. The assembler then gets 10 minutes to rectify the non-conformance. If the non-conformance is rectified within these 10 minutes, the assembler can continue with regular work and no further actions are required. However, if 10 minutes pass or if the assembler estimates that the rectification will take longer than 10 minutes; the assembler must file an NCR.

As described in 5.3.2 Concept 1 - NCR Station, each division has one portable NCR station, tentatively built with Cree Form. The laptop at the station is utilized for NCR related matters exclusively. When the assembler is to file an NCR, he or she fetches the station to the non-conformance. The assembler checks in on the relevant rework code at the same time since the NCR station is located by the time registration clock. The procedure of filing an NCR is listed below. A screenshot of a prototype NCR-filing system is viewed in appendix 7.

Figure 15. Process flow for the final concept (Ejderhov and Åkerlund, 2015).
1. The assembler scans his or her SSOID-card, the barcode of the item and associated ordering documents. This information is automatically imported to the NCR. The numbers can be written manually if no barcodes are available. If the item has a unique serial key, this has to be written manually too. Description of the non-conformance is written manually, as well as the number of faults, choosing category and reason for non-conformance. The input automatically retrieves information of item cost, NCR-history, inventory level, product name, production group, etc.

2. Based on the information provided in the previous step, the assembler can make the following decision:
   a. Scrap the item. This is appropriate when the item is cheap and an off event. The assembler saves the NCR for data, and the inventory level is adjusted automatically. The assembler carries the item to the designated scrap area, checks out of the rework code and proceeds with regular job assignments.
   b. Send the NCR to the associated ME for further investigation. This is appropriate when the item should be reclaimed, when it is expensive, when it has a numerous record of NCRs, when the non-conformance is unable to be rectified at the division or when the assembler is unsure of what approach to choose. A protection label is printed automatically from the printer located at the NCR station. The assembler attaches the label onto the item and carries it to the protected area designated for the ANDON. The ANDON receives the NCR and the responsibility for rectification. A further description of the ANDON function is presented in 5.4.1 ANDON.
   c. Send the NCR to the ANDON at the associated division. The function of the ANDON-person does not exist at the site today but will be introduced with this concept. This option is appropriate when the item is not going to be reclaimed, or when the length of the rectification is estimated to longer than 10 minutes and the required equipment are available at the division. A protection label is printed automatically from the printer located at the NCR station. The assembler attaches the label onto the item and carries it to the protected area designated for the ANDON. The ANDON receives the NCR and the responsibility for rectification. A further description of the ANDON function is presented in 5.4.1 ANDON.
   d. Send the NCR to QE. This is appropriate when the results from tests seem odd. A protection label is printed automatically from the printer located at the NCR station. The assembler attaches the label onto the item. The assembler checks out from the rework code and proceeds with regular job assignments. The QE receives the NCR and the responsibility for further investigation.

3. Whenever the assembler carries the non-conforming item to the protected area, he or she retrieves a replacing item in the same way as today. Recti-
fied material is transported back to inventory.

When an ME receives the NCR, he or she has the following options which he or she bases on the information available in the NCR:
1. Reclaim the item.
2. Use as is. This entails filing a concession.
3. Scrap the item.
4. Start a root-cause investigation.
5. Modify item.

If the chosen alternative is to modify the item, the following options are available:
1. Modification by ANDON. If this alternative is chosen, the non-conformance is sent to the ANDON and then rectified according to 5.4.1 ANDON.
2. Modification by Mechanical Workshop. This concerns material manufactured by the MW.
3. Modification by Tool Shop (Jour). This concerns purchased material. When non-conforming material arrives at TS, the person on call achieves responsibility for its rectification. This person takes care of all rework that is assigned to TS. When no rework is current, he or she can assist the others in TS with their regular work.

Whatever measure was performed, it must be described in the NCR. This information is then automatically sent to the creator of the NCR. The feedback could be shared for instance with email. Every NCR is saved for future statistics, analyzes and decisions.

5.4.1 ANDON
Every division is with this concept assigned one ANDON each, which is a person that rectifies minor non-conformances. The ANDON has a designated workstation where rectifications can be conducted. This workstation contains sufficient tools and equipment. The ANDON is checked in on the rework code when rectifying a non-conformance.

The ANDON function could be replaced by the assembler. This concerns divisions that do not have a fast material flow or an assembly line. When the assembler acts as the ANDON, he or she can rectify the non-conformance. The NCR still must be filed as described above, though.

5.4.2 Logging Rework
All rework of greater length than 10 minutes must be reported. This is conducted by checking in and out of specific rework codes in the current time registration system. The rework codes are specific to each division, and represents product groups. A suggestion is to insert the corresponding rework code as a barcode into the order document. That way the assembler can scan this document right away instead of having to figure out which rework code is correct to use for each case.

The following product groups should have specific rework codes in the time registration system. However, these need to be verified before implementation.

LAB1:
- Rework Gluing room 1
- Rework Gluing room 2
- Rework Gluing room 3
- Rework Pressure Transmitter
- Rework Start line
• Rework Frac line
• Rework Colon line
• Rework Cord
• Rework Amersham WB line

LAB2:
• Rework Uvis
• Rework UV-900
• Rework P1
• Rework UPC
• Rework Prime
• Rework P 960
• Rework Monochromator
• Rework General

LAB3:
• Rework Pumps
• Rework Pump drives
• Rework Valves
• Rework UV
• Rework Small modules
• Rework Frac
• Rework Systems
• Rework Spare parts

CAM1:
• Rework Äktaprocess Test
• Rework Äktaprocess Frame Assembly
• Rework Äktaprocess Cabinet Assembly
• Rework Äktaprocess Cable Assembly
• Rework Uniflux Test
• Rework P.907/908 Test
• Rework Äktaready Test
• Rework Äktacrossflow Test
• Rework Äktapilot Module Test

CAM2:
• Rework BPG Small
• Rework BPG Large
• Rework Pilot
• Rework Process
• Rework XL

• Rework ChromXact
• Rework Minor jobs

CAM3:
Biacore
• Rework Other
• Rework X-100
• Rework T-200
• Rework BC-3000
• Rework BC-4000
• Rework BCC
• Rework BCQ
• Rework Measuring Unit T-200
• Rework Measuring Unit BC-4000
• Rework Measuring Unit Classic
• Rework Buffer Selector BC-4000
• Rework Pumps BC-4000/T-200
• Rework IFC Controller
• Rework Spotpicker
• Rework Digester
• Rework Scanhead Storm
• Rework Typhoon Laser
• Rework Other Optics room
• Rework Other Spare parts
• Wave
• Rework Other
• Rework Group 3520
• Rework Group 3530

5.4.3 Benefits and Costs of the Chosen Concept
This section contains a summary of the benefits and costs that the chosen concept entails. Because of the nature of the advantages that the concept implies, it is difficult, if not impossible, to estimate what the benefits and costs would be in actual figures. However, it is possible to present the benefits and costs by explaining them in words.

Faster process with less non-value adding time
The new process is faster due to several
reasons. Partly because the standardization of the process implies that the affected persons have a clear idea of what action to take. However, it is mostly due to the removal of the current function of the NCR-coordinator. The non-value adding time where the NCR-coordinator reviews the NCRs before it is sent to the responsible person is eliminated. The new concept will not require this review. The time spent on reviewing can be spent on something value-adding instead, such as performing root-cause analysis based on NCR-statistics.

Clarity in the process with easier tools and training for users

The final concept of the rework process offers fewer available approaches and clearer directives on what approach to choose. This implies that the affected persons can make decisions more confident and more similar to others in the same situation. The concept also includes guidelines for future software for registering rework. These two improvements will increase the motivation to follow the new process and to register the rework.

Larger amount of reliable data

The new process makes it easier for the users to both register time and information of rework. This will most likely increase the amount of registered rework, and make it correspond with the reality. The defined time limit (10 minutes) of when to register rework implies that comparisons and analyzes of rework between divisions are enabled. This is because all divisions will register rework under equal conditions and directions.

More reliable data could in the future also entail that less non-conforming material arrives from the suppliers. This is because GEHC could use the data to put higher demands on the suppliers.

Costs

The new process also entails some costs. These costs are training of ANDONs and purchase of the six NCR-stations. The education of the ANDONs is perhaps not necessary for every division. The education is supposed to make the ANDONs aware of the products at their division, and enabling them making appropriate decisions regarding modifications.

The other cost concerns the six NCR stations, which includes purchase of laptops, cameras, scanners, printers and software. However, since another project team already works with the replacement of the old NCR software, the cost for the purchase of that software is not included in this project. That cost is assigned to the other project team. Hence the remaining costs are purchase of the laptops, cameras, scanners and printers.

5.5 ANSWERING THE PROJECT ISSUES

Below follows a summary of the answers to the project issues which has guided the execution of this project.

What is the current state of the rework process at GEHC?

As described in 5.1 MAPPING OF THE CURRENT STATE, the current state of the rework process at GEHC is complicated and problematic. The process does not follow any standard. The process seems to vary from case to case, and also between divisions. The CSM in figure 10 shows a process that offers plenty of available approaches that are arbitrarily
chosen. In addition, the actual process is even more complex. The way of register both time and information about the rework is also quite complicated, due to its insufficient equipment. This causes problems for the involved parties, and it prevents the desired improvement work to reduce rework.

What is GEHCs definition of rework?
The definition of rework that was established together with the employees at GEHC follows: “GEHC’s definition of rework is all the extra work caused by malfunction or material that differs from their specifications. Rework must be reported in order to achieve a real and transparent picture of rework. It can occur everywhere in the factory and can involve all departments.”

How should a process be designed to establish a transparent and real picture of the amount of rework?
In order to achieve a transparent amount of rework, it is required to establish a standardized process for both the performing of rework as well as the registration of rework. These processes have to be clear, easy to understand, easy to use and offer feedback to the creator of each filed NCR. A further description of what such a process requires is presented in 5.2.4 Requirement Specification.

The final concept, described in 5.4 FINAL CONCEPT, was developed to fulfill the requirement specification. It is therefore a good example of how a process should be designed in order to establish a transparent and real picture of the amount of rework.
6 Discussion and Reflection

This section contains a discussion of the execution of this thesis project and its result. The discussion is divided into four different parts. The first part discusses the theoretical framework in relation to the obtained result. The second part contains a discussion of how the methods were conducted, the third part is about the validity of the thesis project and the fourth part is a conclusion of the project. The conclusion presents for instance the relevance of the project result and the lessons learnt during the execution of the project.

6.1 Theory

A major part of the work in this project was dedicated to map the current state. The mapping was conducted with methods that are generally known, which is why these only are described in 4 Method. The theories described in 3 Theoretical Framework were instead used in order to conduct a sufficient development of a new and improved concept for a rework process that falls in line with the orientation and organization goals of GEHC. Since GEHC works with LSS, we wanted the developed concept to also satisfy the requirements for a sufficient process according to LSS.

One of the guidelines of GEHC is right the first time, which is described by George (2010) among others. GEHC also strives for predictability and efficiency, which is described by Goldsby and Martichenko (2005). Both these descriptions recommend establishment of standardized processes. This is why we put a lot of effort to develop a concept that consists of a standardized process. Responsiveness, another guideline of GEHC, highly affects this project since it concerns a process that occurs due to non-conformances. As described by GE (2015), responsiveness is about taking action quickly and synchronized when non-conformances occur. This was also considered when developing the new concept, and we think that we succeeded to develop a concept that is responsive. The final guideline of GEHC; Standardized Flexibility, lies somewhat outside the scope of this project. This is why we did not manage to follow all the guidelines.

If interpreting what George (2010), Goldsby and Martichenko (2005), Salah, Rahim and Carratero (2010) write, LSS strives to reduce the seven wastes. One example of how the developed concept enables this is the elimination of the non-value adding work conducted by the NCR-coordinator. In the current rework process, he has to review the filed NCRs and complete it with additional information before he returns it to the affected ME. Sometimes the gathering of the additional information requires that he walks to the creator of the NCR to ask additional questions of the non-conformance. With the new concept, the additional information is added automatically, and the NCR is sent directly to the affected ME. This releases working time for the coordinator to perform value-adding work instead. It also reduces waiting time and motion, since the ME does not have to wait on the coordinator to review the NCR and because the coordinator no longer has to walk to the creator to ask additional questions. Another waste that also is affected by this concept is the defects. Since the concept enables obtaining a true picture of the amount of rework throughout the factory, it is possible to identify the causes of the rework. Hence, it is also possible to eliminate these causes.

6.2 Method

The planned project process deviates a bit from how it actually was conducted. We created a very detailed plan because we wanted to assure that we had enough time assigned to each phase. It was also because we wanted to assure that we conducted all activities that we considered necessary to satisfy the projects purpose. However, this means that if the nature of the project differs from the expected, the plan might require some adjustments. This happened to us a couple of times. However, we do not consider it as a failure that
the final performance differs from the planned. On the contrary, we consider the difference as a proof of our responsiveness and ability to change in order to achieve the best result possible for the project. This is a lesson that we have learnt from earlier projects during our education.

An example of such an adjustment is the development of the NCR-process. Initially our main assignment was to develop a concept for a future rework process. As time went by, it became more and more obvious that we would have to include the NCR-process in this development, even though we initially had planned to exclude the NCR-process. This process turned out to be so deeply involved in the rework process, that it was not possible to exclude it and still achieve a sufficient concept. This is why the NCRs were attended in this project, even though that was not the plan from the beginning.

Some of the tools often utilized in LSS are presented in figure 3. The figure visualizes some of the tools typical for Six Sigma and Lean Production each, together with a set of tools that are common for both methodologies. Most of the common tools have actually been utilized throughout this project. These methods are brainstorming, process mapping and standardization. All of these have been proven to be beneficial to the projects result. The one tool that was not utilized is mistake proofing. However, this is a tool that would be appropriate to use in the continued work with the concept. Many of the tools of Six Sigma are methods for statistical analysis. Since this project is not based on large amounts of data, it was not relevant to utilize that kind of tools.

The response frequencies of both surveys calculated in 5.1.2 Surveys are considerably lower than 50 %. Karlsson et al. (2008) mean that the result is not representative for the target group if the fall off is larger than 50 %. However, since the surveys were distributed by designated BTLs or other executives, it is uncertain how many of the blue and white collars that actually got the opportunity to partake in the survey. If we had conducted the distribution instead, the amount of distributed surveys would have been known. Then the calculation of the response frequency would have been reliable, and probably higher too, since we suspect that not all 250 blue collars and 90 white collars got the opportunity to answer the survey. This is why we decided to use the result of the surveys anyway, even though the response frequency was lower than recommended.

It is also worth mentioning that question 10 on the white collar survey gave examples of how to answer the question. This makes it difficult to know if they chose these answers of “free will” or if they were influenced by the given examples. However, we do not think that this affects the final outcome of the project.

When performing the Stream Mapping during focus group 1, two problems occurred. First, it was difficult for the participants to understand what the labels of the categorizations meant. This is probably due to the fact that we also had difficulties to understand them. This in turn entailed that this method required more explanation than planned, and hence took longer time. This led to problem number two; the participant did not have enough time to finish their FSMs. The explanations extended over parts of the time devoted for the creation of the FSMs. The creation of the FSMs also required more time than expected. This is probably because the participants interpreted the different activities differently depending on which division they belonged to. However, the discussions during this exercise turned out to be beneficial for the continued work. As described in 4.3.3.1 Stream Mapping, we thought that the method would be sufficient after the adjustments were made. However, we think that if we were to repeat this project, we would choose another method than VSM for this matter.

6.3 Validity
We put a lot of effort on combining several methods in order to achieve valid results. For
example, we conducted three different methods for gathering information when mapping the current state (interviews, observations and surveys). Each of these three methods was in turn conducted with different people and at different occasions. Furthermore, the essence of the obtained result from the mapping of the current state was discussed again during parts of the focus groups.

Another example is when the prototype of the NCR was validated. We presented it to the ME and one assembler of each division, one division at a time. Each presentation included discussion of the prototype which sometimes resulted in adjustments. When the adjustments were made the prototype was presented to the next division.

A third example is the determination of when rework should be registered. An early suggestion was to classify the different types of rework into “rework that must be registered” and “rework that does not have to be registered”. Hence, the type of rework would be decisive whether it should be registered or not. However, the idea was rejected during discussions with concerned employees, with good reason. The discussion resulted in a better idea, which became a part of the final result.

Because of the carefully performed validation of each step in the project, we can feel confident with the obtained result. This proved to be extra important during the Stream Mapping. Like we discussed in 6.2 Method, the Stream Mapping did not result as we had expected. But since we had other complimenting methods for analyzing the rework process, the analysis turned out well anyway.

Another benefit of the carefully performed validation and extensive involvement of the employees is that the risk for resistance of change is probably decreased.

6.4 Conclusion
This thesis contributes with knowledge and information of the current state of the rework process at GEHC. It is a thoroughly performed mapping which is based both on opinions and knowledge of the employees, and on observations conducted by us as external parties. The result is mainly relevant for the people at GEHC in Umeå. The presented concept that is based on the knowledge of the current state is mainly relevant for the user and actors of the rework process. This is especially because the concept was developed in close cooperation with the users, and because it will affect their daily job assignments if implemented.

By reducing the amount of rework in the factory, unnecessary costs will be reduced correspondingly. This will contribute to a positive development of the economic situation at the company. This in turn can hopefully lead to that the company can continue to grow in Umeå. This would contribute to more job opportunities in Umeå, and hence enable a social sustainable development. Companies that can continue to grow in minor communities contribute to an ecological sustainable development due to for example less centralization and less commuting.

One of the lessons learnt during this project is to remain critical to given descriptions of problems, and not just accept them. It is essential that one understands the problem completely before one tries to solve it. It is also important to set appropriate delimitations.

Finally, we want to stress that it is important to assure that the obtained data is correct, before one tries to improve these data. This concerns all areas, not just this thesis project. This thesis sets an example of the first leap towards collecting true data.
7 RECOMMENDATION

At first, it is recommended that GEHC should replace the current NCR software with a new software that fulfills the requirements presented in 5.2.4 Requirement Specification. The new NCR system should also preferably be designed as the system described in 5.4 FINAL CONCEPT.

GEHC is also recommended to verify and implement the concept described in 5.4 FINAL CONCEPT. This concept offers a standardized rework process that would improve the current state and enable transparent rework. It is also a concept without major investments or changeovers.

The rework codes in the time registration system should be utilized when registering rework. This would allow a higher resolution on collected data, which would facilitate future improvement work. This is because it would be easier to track the rework status at each project type. 5.4.2 Logging Rework presents how such rework codes could be formed for each division. However, these codes require verification before implementation.

However, the final recommendation to GEHC is to strive to attain the concept presented in 5.3.4 Concept 3 - Advanced. One of the advantages of this concept is that it is a major leap towards a paperless production. It is also an appropriate update of concept 1 - NCR Station, since concept 1 is a step in the right direction towards concept 3.
References


The first three weeks of the project became irrelevant to this master thesis due to a change of direction in the project.
Vill du ha chansen att vinna en gratis lunch?

Hjälp oss två studenter med det som står i texten nedan så är du med i utloppningen av lunchkuponger på restaurangen Drop Inn!

Vi är två studenter som går sista året på Civilingenjör – Produktionsutveckling vid Luleå tekniska universitet. Vi gör just nu vårt examensarbete här på fabriken, vilket kommer pågå fram till slutet på maj. En del av det arbetet handlar om att ta reda på vad ni menar med ordet omarbete, och det är därför vi har skickat ut den här enkäten till dig!

Det är helt frivilligt att fylla i den här enkäten, men vi vore jättetacksmå om du kunde hjälpa oss med vårt arbete genom att göra det. Det är bara sju frågor så det går ju i ett naf!

Dina svar kommer att vara anonyma. Vi kommer att sammanställa och sortera svaren efter vilka avdelningar ni jobbar på, och när det är gjort kommer enkätarna att förstöras. Resultatet av vårt arbete kommer rapporteras i början av juni.

Har du några frågor kan du antingen komma till vårt kontor längst in i IT-korridoren (sista dörren till vänster när du går mot receptionen från fabriken), eller kontakta oss via telefon eller mejl. Om du vill kan du även kontakta vår handledare, Andreas Parment.

Tack! /Amanda och Cecilia

Cecilia Ejderhov
Amanda Akerlund
Telefon

Andreas Parment
Appendix 3: Survey – Blue Collar Workers (2/5)

Fråga 1. På vilken avdelning jobbar du?
- CAM 1
- CAM 2
- CAM 3
- Tool Shop
- Mechanical Workshop
- LAB 1
- LAB 2
- LAB 3
- Incoming Inspections
- Receiving & Shipping

Fråga 2. Kryssa i de aktiviteter rörande omarbeten som du vanligtvis stämplar om för
(Åldrig om du stämplar i flera alternativ.)
- Felsökning
- Jämföra artikel med specifikation
- Modifiera artiklar
- Byta ut felaktiga artiklar
  inkl. Monter och ihop
- Rätta till handhavande fel
- Omtest
- Kontrollera lager
- Fylla i NCR
- Fylla i omarbetsskott
- Väntetid på omarbete
- Transport av felaktiga artiklar till annan avdelning
- Beslutsfattning om åtgärd

Kommunikation kring omarbeten, som du stämplar om för, med åldrig om du stämplar i flera alternativ.
- Prod. tekniker
- Tool Shop
- Incoming Inspections
- Prod. ledare
- Spindeln
- Leverantör
- Receiving & Shipping
- Material & Production Planning
- Övrigt

- Övriga aktiviteter:
Fråga 3. Kryssa i de aktiviteter rörande omarbeten som du vanligtvis utför. (Om du kryssar i flera alternativ.

☐ Felsökning
☐ Jämföra artikel med specification
☐ Modifiera artiklar
☐ Byta ut felaktiga artiklar
☐ Korrigera ICR
☐ Kontrollera lager
☐ Fylla i NCR
☐ Fylla i omarbetsskal
☐ Väntetid pga omarbete
☐ Transport av felaktiga artiklar till annan avdelning
☐ Beslutsfattning om åtgärd

Kommunikation kring omarbeten med flera alternativ:

☐ Prod tekniker
☐ Tool Shop
☐ Incoming Inspections
☐ Prod Ledare
☐ Spindeln
☐ Leverantör
☐ Receiving & Shipping
☐ Material & Production Planning
☐ Övrigt

☐ Övriga aktiviteter:

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________

Fråga 4. Ansvar för omarbetarprocessen skiljer inom gruppen på din avdelning, i sådana fall hur?
Fråga 5. Kryssa i de aktiviteter som du anser vara omarbete

- Felsökning
- Jämföra artikel med specification
- Modifiera artiklar
- Byta ut felaktiga artiklar (inkl. Monteras i dator och i hop)
- Rätta till handhavande fel
- Omtest
- Kontrollera lager
- Fylla i NCR
- Fylla i omarbetsslankett
- Väntetid pga omarbete
- Transport av felaktiga artiklar till annan avdelning
- Beslutsfattning om åtgärd

Kommunikation kring omarbete med i du får kryssa i flera alternativ:

- Prod tekniker
- Tool Shop
- Incoming Inspections
- Prod ledare
- Spindeln
- Leverantör
- Receiving & Shipping (logist)
- Material & Production Planning (logist)
- Övrigt

- Övriga aktiviteter:

Fråga 6. Var på tidsskolkan ligger gränsen för att stämpla omarbete idag? Kryssa på skalan!

Fråga 7. Var på tidsskolkan tycker du gränsen ska ligga för att stämpla omarbete? Kryssa på skalan!
Tusen tack för att du har hjälpt oss! Nu till det roliga...

Skriv upp ditt namn och telefonnummer/avdelning här nedanför om du vill delta i utloppningen av lunchkuponger på restaurangen Drop inn. Dessa uppgifter kommer förstöras när utloppningen är genomförd, och kommer inte kopplas ihop med dina svar.

Denna sida räds ut och lämnas in till ansvarig på din avdelning, tillsammans med ifylld enkät senast fredagen den 27 februari 2015.

Namn: _____________________________________________

Telefonnummer/avdelning: ________________________________

Kryssa i den här rutan om du även skulle vilja delta i en fokusgrupp! Där kommer vi diskutera bland annat hur man skulle kunna förbättra omarbetningsprocessen, göra rapporteringen enklare, belysa problem, samt övriga frågor som kan uppkomma. Mötet kommer hållas vid ett tillfälle och beräknas ta ungefär 1 timme. Du behöver inte kryssa i den här rutan för att vara med i utloppningen.
Vill du ha chansen att vinna en gratis lunch?

Hjälp oss två studenter med det som står i texten nedan så är du med i utloppningen av lunchkupanger på restaurangen Drop Inn!

Vi är två studenter som gör sista året på Civilingenjör - Produktionsutveckling vid Luleå tekniska universitet. Vi gör just nu vårt examensarbete här på fabriken, vilket kommer pågå fram till slutet på maj. En del av det arbetet handlar om att ta reda på vad ni menar med ordet omarbete, och det är därför vi har skickat ut den här enkätan till dig!

Det är helt frivilligt att fylla i den här enkätan, men vi vore jämntacksamma om du kunde hjälpa oss med vårt arbete genom att göra det. Det är bara elva frågor så det går ju i ett nafs!

Dina svar kommer vara anonyma. Vi kommer att sammanställa och sortera svaren efter vilka avdelningar ni jobbar på, och när det är gjort kommer enkätorna att förstöra. Resultatet av vårt arbete kommer rapporteras i början av juni.

Har du några frågor kan du anstningen komma till vårt kontor längst in i IT-korridoren (sista dörran till vänster när du går mot receptionen från fabriken), eller kontakta oss via telefon eller mejl. Om du vill kan du även kontakta vår handledare, Andreas Parment.

Tack! /Amanda och Cecilia

Cecilia Ejderhov  cecilia.ejderhov@ge.com
Amanda Åkerlund  amandaakerklund@ge.com
Telefon  (0901) 50009
Andreas Parment  andreas.parment@ge.com
Fråga 1a. Vilken avdelning tillhör du?

□ Configured & Advanced Mfg
□ Lab Equipment Mfg
□ Advanced Machining
□ Material:
□ Production Preparation
□ Material & Production Planning
□ Project & Process Operations:
□ Manufacturing Engineering
□ Project Office
□ Övrigt.
□ Logistics:
□ Incoming Inspections
□ Receiving & Shipping

Fråga 1b. Jag jobbar mest mot denna avdelning:

□ Felsökning
□ Jämför artikel med specification
□ Modifiera artiklar
□ Byta ut felaktiga artiklar (inkl. Montera idrar och loper)
□ Rätta till handhavande fel
□ Ömtest
□ Kontrollera lager
□ Fylla i NCR
□ Fylla om arbetsblankett
□ Väntetid pga omarbete
□ Transport av felaktiga artiklar till annan avdelning
□ Beslutsfattning om åtgärd

Kommunikation och kontakttytor kring omarbete med denna kryssa i flera alternativ:

□ Prod.tekniker
□ Tool Shop
□ Incoming Inspections idag
□ Prod.leдаре
□ Spindeln
□ Leverantör
□ Reception & Shipping
□ Material & Production Planning idag
□ Konstruktör
□ Övrigt

□ Övriga aktiviteter:
Fråga 3. Kryssa i de aktiviteter som du anser vara omarbete
(Du får kryssa flera alternativ)

☐ Felsökning
☐ Jämföra artikel med specification
☐ Modifiera artiklar
☐ Byta ut felaktiga artiklar
  (inkl. Montera isb. och rihopp)
☐ Rätta till handhavandefel
☐ Omtast
☐ Kontrollera lager
☐ Fylla i NCR
☐ Fylla i omarbetsskalldett
☐ Väntetid pga omarbete
☐ Transport av felaktiga artiklar till annan avdelning
☐ Beslutsfattning om åtgärd

Kommunikation och kontakttytor kring omarbete med (Du får kryssa flera alternativ):

☐ Prod.tekniker
☐ Tool Shop
☐ Incoming Inspections IQO
☐ Prod ledare
☐ Spindeln
☐ Leverantör
☐ Receiving & Shipping lager
☐ Material & Production Planning
☐ Konstruktor
☐ Övrigt

☐ Övriga aktiviteter:


Fråga 4. Redovisar du tiden för omarbete, i så fall, under vilken LTR-kod?
   (Ex LA = Line operations, LA = Quality, CSSx, NCR eller LA = Quality, CAPW)

Fråga 5. Var på tidsskalan tycker du gränsen ska ligga för operatörer att stämpla omarbete?
   (Kryssa på skalarna)

<table>
<thead>
<tr>
<th>5m</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>1h</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>1d</th>
<th>Aldrig</th>
</tr>
</thead>
</table>
Fråga 6. Var på tidsskalan tycker du gränsen ska ligga för tjänstemän att rapportera omarbete? (Kryssa på skalan)

<table>
<thead>
<tr>
<th></th>
<th>5m</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>1h</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>1d</th>
<th>Aldrig</th>
</tr>
</thead>
</table>

Fråga 7. Anser du att omarbetsprocessen skiljer sig på något sätt mellan dig och dina kollegor, i sådana fall hur?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Fråga 8. Hur anser du att omarbetsprocessen fungerar idag? (Kryssa på skalan)

<table>
<thead>
<tr>
<th>Inte alls</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Mycket bra</th>
</tr>
</thead>
</table>

Fråga 9. Hur skulle man kunna förbättra omarbetsprocessen?

________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Fråga 10. Vilka mätetar för omarbete är intressanta för dig? (F. ex: tid, antal, osv)

________________________________________________________________________
________________________________________________________________________

Fråga 11. Hur skulle det ideala loggningssystemet av omarbete fungera enligt dig? Rita gärna på nästa sida!
Tusen tack för att du har hjälpt oss! Nu till det roliga...

Skriv upp ditt namn och telefonnummer/avdelning här nedanför om du vill delta i utloppningen av lunchkuponger på restaurangen Drop Inn. Dessa uppgifter kommer förstöras när utloppningen är genomförd, och kommer inte kopplas ihop med dina svar.

Denna sida rivas ut och lämnas tillsammans med fylld enkät tillbaka till personen som delade ut enkäten, senast fredagen den 27 februari 2015.

Namn: ________________________________________________________________

Telefonnummer/avdelning: ______________________________________________

Kryssa i den här rutan om du även skulle vilja delta i en fokusgrupp! Där kommer vi diskutera bland annat hur man skulle kunna förbättra omarbetssprocessen, göra rapporteringen enklare, belysa problem, samt övriga frågor som kan uppkomma. Mötet kommer hållas vid ett tillfälle och beräknas ta ungefär 1 timme. Du behöver inte kryssa i den här rutan för att vara med i utloppningen.
Appendix 5: Stream Mapping Categories

- **Necessary No Value-loss (NNVL)**
  - NNVL involves necessary activities or decisions that do not contribute to any value-loss nor cost-adding for the faulty product or item.

- **Necessary Cost-Adding (NCA)**
  - NCA involves necessary activities or decisions that do not contribute to any value-loss but is cost-adding for the faulty product or item.

- **Cost-Adding (CA)**
  - CA involves activities or decisions that is only cost-adding for the faulty product or item.
Appendix 7: NCR-prototype

Step 1.
Scan or write the designated data in the Input box. Be as specific as you can in the fault description.

Step 2.
Analyze the information about the faulty item in the Output box, such as price and NCR history.

Step 3.
Based on the information from the Output box, choose an approach for the faulty item and send the NCR.

SSOID: 3
Item no: 4
Order no: 1
Category: Disturbance Error
No of faults: 100
Reason for error: Faulty on arrival

Fault description:
The non-conforming item had...

Upload pic/video: C:\Users\[user]\[file path]  Browse

Step 2. Output:
Contact person: Lotta
Item name: Nut 4
Inventory level: 150
Price/pc [SEK]: 2
NCR History: 10
Product cost for this case [SEK]: 200

Product name: Uniflex 20
Product no: POS45968
Product type: ISO 13485
Production group: LAB 1
Order quantity: 1
Document no: D03059416
Serial no: SE94593

Step 3. Approach:
- Scrap
- Send NCR to ANDON or operator for modification
- Send NCR to HR for investigation
- QE
- Send NCR

(1/3)
Appendix 7 NCR-prototype

Information

- **Contact person:** Lotta
- **Category:** Disturbance Error
- **Reason for error by op.:** Faulty on arrival
- **Reason for error by AN.:** Unknown

- **Item name:** Nut 4
- **Inventory level:** 850
- **Price/pc [SEK]:** 2
- **NCR history:** 10
- **Number of faults:** 100
- **Product cost for this case [SEK]:** 200

- **Product name:** Uniflex 20
- **Product no.:** PO945974
- **Product type:** ISO 13485
- **Production group:** LAB 1
- **Order quantity:** 50
- **Document no.:** DO5684152
- **Serial no.:** SE84199

**Fault description:**

The non-conforming item had...

Investigation

- **Reason for error:** Unknown

- **Approach:**
  - Scrap
  - Send to ME
  - Modification

- **Modification description:**
The item was scrapped due to...

Pictures or videos

- Image of two screws
Appendix 7: NCR prototype