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Improving Production System Performance by Approaching Problem Solving Procedures for Components in Advanced Technology Manufacturing

Master's Thesis in the Master's Programme
Production Engineering

LUCY AKSÖZ
AMANDA SAARELAINEN

Department of Technology Management and Economics
Division of Supply and Operations Management
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LUCY AKSÖZ
AMANDA SAAREL AINEN

Examiner: Lars Medbo
Tutor, Chalmers: Patrik Fager
Tutor, DSC: Fredrik Larsson

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Department of Technology Management and Economics
Division of Supply and Operations Management
Chalmers University of Technology
SE-412 96 Gothenburg, Sweden
Telephone: + 46 (0)31-772 1000

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ABSTRACT

In advanced technology manufacturing such as in the security and defence industry, complex end-products are built from expensive components for which high quality levels are essential. The concept of Lean production and its practices has for decades supported companies in their development of quality focused products. Solving problems related to the components of a product is a daily task performed at the case company. Today, this problem solving is carried without any standards or guidelines. Therefore, the purpose of this thesis is to identify how problem solving procedures in advanced technology manufacturing – used for resolving component problems in the production flow – can apply Lean practices as a means to increase the production system performance. Performance in this context refers to improvement of the production rate of the products. The expected outcome is a standard for how to resolve problems related to components in the production of advanced technology.

The suggested procedure and its standard were developed through a case study followed by analysis of quantitative and qualitative data using value stream mapping. The purpose was fulfilled by assessing application of Lean practices in currently used problem solving procedures and this assessment was used as a foundation for the procedure.

The procedure includes two separate parts that are intertwining and covers both short-and long-term solutions to a identified problem. The procedure is an example of how Lean practices can be applied in administrative and creative processes.

The theoretical contribution is application of Lean practices and methods in administrative and creative processes in an organisation with complex products and high quality demands. The practical contribution is a standard for how to resolve component problems in advanced technology manufacturing as a means to improve the production system performance. Further research will be to investigate if the suggested problem solving procedure can be used in other environments, such as high volume production, as well as see how technology trends, e.g. Internet of Things and Industry 4.0, affects the problem solving procedures.

Keywords: Lean practices, advanced technology manufacturing, problem solving procedure, standard, value stream mapping

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Lucy Aksöz and Amanda Saarelainen, Gothenburg, May 2018

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GLOSSARY

DCS – Defence and Security Company

Genchi Genbutsu – Go and see

GG – Guldgruvan (The gold mine)

Hansei – Reflection

Jidoka – Quality detection

Kaikaku – Radical improvements

Kaizen – Continuous improvements

LT – Long-term

MM – Materialmötet (The material meeting)

NCR – Non-conformance report

PDCA – Plan-do-check-act cycle by Edward Deming

Sensei – Master

Shu-Ha-Ri – learning cycle in three phases

ST – Short-term

VSM – Value Stream Mapping

Yokoten – horizontal communication

1 INTRODUCTION

In this chapter the theoretical and industrial background of the thesis are presented, accompanied by the purpose, expected outcome, problem definition and scope.

1.1 THEORETICAL BACKGROUND

In advanced technology manufacturing, complex end-products are built from expensive components for which high quality levels are essential. Here, quality problems in production must be addressed quickly and the solutions employed must be viable over the long-term. Lean production – originally an adoption of the management system used by the world-leading car manufacturer Toyota – has for decades supported companies in their development of quality focused operations that strive for perfection through relentless problem solving and overall continuous improvements (Liker & Hoseus, 2008). There is obvious potential for Lean production to be effective in advanced technology manufacturing. In advanced technology manufacturing will even the smallest problems be addressed, not only temporary but also permanently to ensure that same problem does not reoccur. The problem solving procedure in advance technology manufacturing is therefore vital to look over since low quality solutions are hindering the production rate as well as utilises more resources than needed.

Lean production has been applied in other areas than the manufacturing (Hines, et al., 2004) where it initially had its success through high productivity, flexibility and quality (Krafcik, 1988). Emiliani & Stec (2005) recognize a trend in manufacturing businesses where Lean practices are now adapted to other processes in the organisation than the manufacturing operations, such as engineering and accounting. By adapting Lean practices throughout the organisation the Lean enterprise is created (Murman, et al., 2002). Within a Lean enterprise, the focus is always on creation of value for the customer (Locher & Keyte, 2016; Murman, et al., 2002). The success of lean has been attributed not only to how the production system is designed, but also to the organisational culture that Lean thinking both require and create (Liker & Hoseus, 2008). The benefits of a Lean enterprise is that everyone in the organisation knows their role, that the organisation is aligned towards common strategic goals, and that the organisation continuously improves all of its activities (Locher & Keyte, 2016). At Toyota, problem solving is key for continuous improvements and is one of the four main principles of Lean thinking. Teamwork based on cross-competencies and effective communication is essential for high level problem solving capabilities. However, to make problem solving truly effective, standards around the problem solving process must be applied (Liker, 2004). Problem solving is one of the four principles within Lean and problem solving is important to be executed by teams (Liker & Meier, 2006). When solving a problem with teamwork, communication is crucial for a successful solution. Within Lean, people with different competences creates a team (Liker & Hoseus, 2008), hence being a cross-competence team (Irirna, 2016), from this it is obvious to have effective communication.

Standards are guides in what is to be achieved and how it is achieved (Zandin & Maynard, 2001) and if used correctly there is improved stability, flexibility and quality and it creates a platform for learning at both individual and organisational level (Emiliani, 2008). Standardised work is a fundamental part of Lean production, making up the foundation of continuous improvements by creating stabilised processes that can be improved over time (Liker, 2004), hence also one of the principles within a Lean enterprise. Standards are the foundation for continuous improvement since it creates a stabilised process that later can be improved (Liker, 2004). At Toyota problem solving is also done according to standards (Liker & Meier, 2006) and all employees in the organisation are being educated in how to efficiently solve problems according to the standards (Liker, 2004). Some of the problem solving standards at Toyota are A3 reports, 5-Why and problem solving *kata*. Standards will not only improve productivity but also empower the people within the organisation working with the standards (Liker, 2004).

1.2 INDUSTRIAL BACKGROUND

The industrial background of the current thesis involves a defence and security company (further referred to as "DSC") striving to increase their production. The company have today tried to increase their production rate and this has led to emerging quality problems. The time it takes to solve these problems are limiting DSC from increasing the production rate further. Today DSC are solving component problems, both short- and long-term, following no standards or guidelines. The problems are solved mainly by using one of three problem solving procedures and the choice of which to use is not specified.

1.3 PURPOSE

Solving problems related to the components of a product is a daily task performed at DSC. When having a functional layout production system, all equipment of the same type is collocated (Bellgran & Säfsten, 2010). If one component turns out to be faulty, the component will not lead to stoppage in production but the product affected by the faulty component will be idle. The product itself will then be idle until the faulty component is solved resulting in prolonged production lead time. If the faulty component were to be exchanged, it would result in another product missing a component. This is due to minimized inventory of components and a just-in-time principle (getting the component right when it is needed (Liker, 2004)). The time it takes to solve the problem temporary is therefore essential to decrease in order to not prolong production lead time for a product with a faulty component. In addition, the root-cause to the problem has to be identified to prevent the same problem from occurring in the future, the same way as they are solving problems at Toyota (Liker, 2004). *Therefore, the purpose of this thesis is to identify how problem solving procedures in advanced technology manufacturing – used for resolving component problems in the production flow – can apply Lean practices as a means to increase the production system performance.* Performance in this context refers to improvement of the production rate of the products. The expected outcome is a standard for how to resolve problems related to components in the production of advanced technology.

Within production there are various types of component problems which occur by different reasons. At DSC there are currently different procedures for solving component problems. The choice of which problem solving procedure to use for a certain component problem is based on previous experience with similar component problems. In order to understand how the currently used procedures are applied to the typology of component problems, the first research question is:

RQ1: Which type of component problem are resolved by which problem solving procedure?

Although component problems are believed to impact the performance, neither the mechanisms behind the impact, nor the extent of the impact, are known today. Therefore, identification of what impact the component problems and the different problem solving procedures have will be performed. The mechanism of the impact is vital to understand when developing the standard later presented to the case company. Therefore the second research question states:

RQ2: What impact do component problems and their associated problem solving procedures have on the production rate?

Lean practices are known for reducing waste in processes, thereby increasing the process performance and, by extension, the production system performance. The currently used problem solving procedures may be applying Lean practices to greater or lesser extent, and therefore may involve varying amounts of waste. Identification of how Lean practices are utilized in the current problem solving procedures would allow for the current amounts of waste to be assessed, resulting in knowledge that can be used to improve the procedures and to develop a new improved standard for the case company to adopt. Therefore the third research question states:

RQ3: How are Lean practices applied to the currently used problem solving procedures?

The current problem solving procedures may be far from optimal and there may be ways of improving the current procedures in benefit of the production performance. If a new problem solving procedure can be designed, based on knowledge from literature combined with the knowledge attained from answering the previous research questions, this new procedure could serve as standard by which the current procedures can be improved, and possibly replace the current procedures entirely. This leads to the fourth research question:

RQ4: What problem solving procedure design would improve the production system performance over the procedures used in the current state?

The first question creates an understanding for the current state, while the second question researches the impact of the current state on the production system performance. Lean practices are often used to increase the production system performance, and in order to understand how Lean practices are used in the current used problem solving procedures, the third question will be answered. The answers from the first, second and third question will act as guidance for the fourth question. In the fourth question will a standard be developed, which will be delivered to DSC.

The project contributes to the understanding of Lean practices in administrative processes within advanced technology manufacturing, especially in the creative process of problem solving, which is a part of becoming a Lean enterprise.

1.4 SCOPE AND DELIMITATIONS

The thesis studies the problem solving procedures' impact on production system performance at a defence and security company. The research investigates the problem solving procedures related to one product, its components and the people involved in the procedures. Hence, procedures related to other products are considered to the extent they are relevant for the product in focus, but will not be used as basis for improvement suggestions.

The improvement of the production system performance will be measured in reduced lead time for solving problems, which increases the production rate. The financial consequences of the improvement will not be analysed, but parts of the thesis may serve as an aid in a financial analysis since an increase in productivity can affect the unit costs.

In terms of efficiency of the problem solving procedures, this includes how to improve the current procedures, or creating a new procedure, and how to choose which procedure to use depending on the typology of the component problem. The solutions generated by problem solving procedures consider both short- and long-term solutions to the component problems. In addition, the problem solving procedures will be evaluated and a suggestion for improvement, which can be a new problem solving procedure, will be developed but not implemented.

1.5 REPORT OUTLINE

This thesis is organised in eight main chapters and a set of appendices suited for this project. This chapter describes the background of the project and its purpose, while also presenting the research questions and the scope. The second chapter presents the theoretical framework, detailing a set of Lean concepts that are crucial for problem solving and that are used in the analysis of the current practice at the DSC. The third chapter describes the research method used for collecting and analysing the data in this project, and how the analysis outcome was used to derive answers to the research questions. In the fourth chapter the results from the empirical findings from the case study is presented. This is followed by the fifth chapter where the empirical data is analysed with the theoretical framework to formulate a description of the current state. The sixth chapter describes the steps taken for creating the future state, followed by a presentation of the future state. In the seventh chapter the future state and the findings are discussed and put into a broader perspective, and directions for further research are formulated. Finally, in chapter 8, the conclusions of the thesis are formulated and the contributions made by the thesis to practice and theory are outlined.

2 THEORETICAL FRAMEWORK

In this chapter, the theoretical framework that creates the basis for this project is presented. The examined topics are Lean Practices, Value Stream Mapping, Problem Solving Methods and Kanban Project Management. Current problem solving procedures will be examined in how different Lean Practices are applied, while Value Stream Mapping is a method for analysing both qualitative and quantitative data as for development of a future state. The future state of the problem solving procedure will be inspired of Problem Solving Methods at Toyota and different Lean Practices will be applied. Kanban Project Management can be used to manage all different problems as they are proceeding for a solution.

2.1 LEAN PRACTICES

Production companies around the world adopt different strategies and methods to be competitive in the business of production. The factors that differentiate successful companies from the once that are not so successful are simple: they pay attention to their customers and listen to their demands, which is the key for competitiveness. These companies are usually good at producing products which are better in quality, cheaper in price, faster to produce and experts at responding to changes on the market (Nicholas, 2011). Toyota has become famous for their production system, which is know as Lean Production (Bellgran & Säfsten, 2010), and fulfills the needs of better performance in terms of higher quality, lower production cost, faster production and better responsible to market changes (Liker, 2004).

Toyota production system is an adoption of Ford's production system for a context with scarce resources, which was the situation for Japanese companies following World War II. Toyoda, the founder of the Toyota production system, saw the need of a production system that were less wasteful and less costly, but at the same time more efficient and flexible (Nicholas, 2011). This production system has been visualized as the "TPS house", which consists of a foundation, two pillars and a roof. The foundation consists of standardised and stable processes, continuous improvements, Toyota's philosophy and levelled production (necessary to keep the system stable and allowing minimum inventory). There are two pillars representing just-in-time and *jidoka* (quality detection). On the pillars rests the roof, which represents the goals of best quality, lowest cost and shortest lead time (Liker, 2004). The TPS house can be found in Figure 2.1.

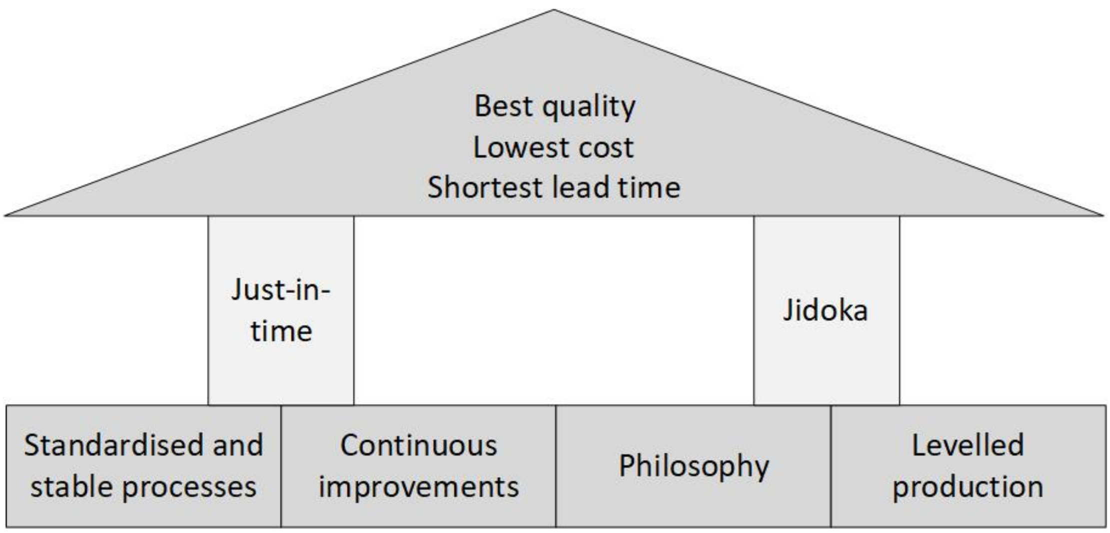

Figure 2.1: TPS house, inspired by Liker (2004).

Lean production can also be respresented by principles in the 4P model, where the Ps are: Philosophy, Process, People & Partners and Problem solving (Liker, 2004), which is visualized in Figure 2.2. Liker (2004) argues that most manufacturing companies focus only on the principle process and that this hinders them from reaching the maximum performance of the organisation. By adding the three other Ps, a company can lay a foundation for contunious improvement, which is the basis in Lean production. This is due to the fact that everything can always improve and be closer to perfection which is the unreachable goal of Lean (Liker, 2004).

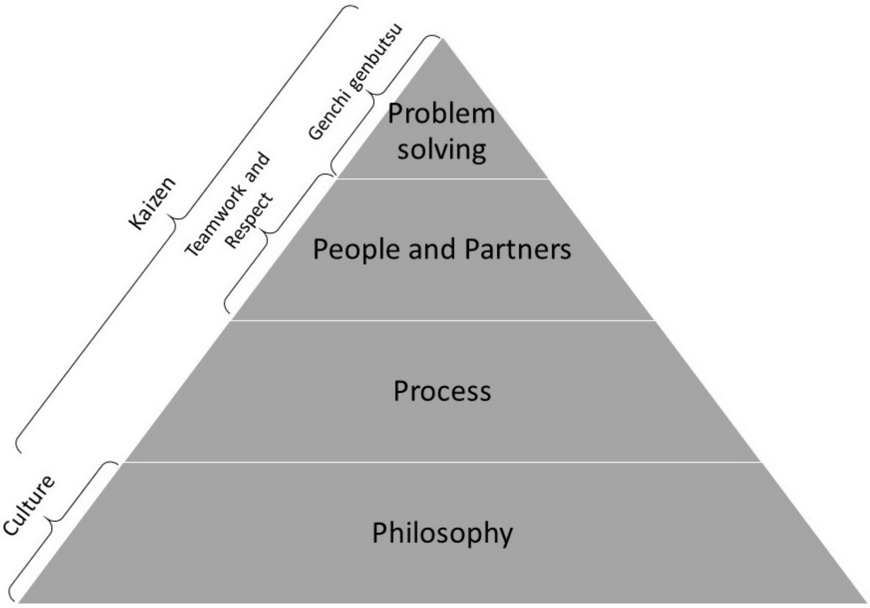

Figure 2.2: 4P model, inspired by Liker & Meier (2006).

The **philosophy** sets the foundation for the other three principles (Liker & Meier, 2006) which is visualized in Figure 2.2 above. Each and every company has to create its own philosophy and truly live it. One cannot copy the philosophy from Toyota, but can be used as inspiration. Toyotas own philosophy comes to life in its culture and its leaders. The leaders have learned that the right results will come if one follow the right **processes** (Liker & Meier, 2006). The focus of the processes is to eliminate waste by implementing Lean tools such as pull system, detect quality issues and standardise tasks (Liker, 2004). To truly live the philosophy throughout the organisation it is important to have the right **people and partners** and develop them (Liker & Meier, 2006). The development of people and partners are not done individually but in teams. Teamwork at Toyota is considered to be advantageous compared to working alone (Liker & Hoseus, 2008). At Toyota, **problem solving** is often done in teams. Problem solving is important to be executed in a stable and good way and is the way to reach perfection through continuous improvements (Liker & Meier, 2006).

To simplify the concept of Lean, it can be said to be a tool which is used to improve quality since it cuts time delays between the processes in production (Liker, 2004). Furthermore, different Lean practices applicable for problem solving procedures, and their importance in the 4P model is described. The chose practices are important for this project since they are applicable for administrative processes as well as for production processes. The focus are lean practices that are either directly organisational, e.g. Toyota culture, or practices that can be adapted to the purpose of this thesis, e.g. *genchi genbutsu*, and practices found in literature regarding administrative processes, e.g. pull system.

2.1.1 TOYOTA CULTURE

The Toyota culture is a part of the philosophy and philosophy is a part of the 4P model seen in Figure 2.3.

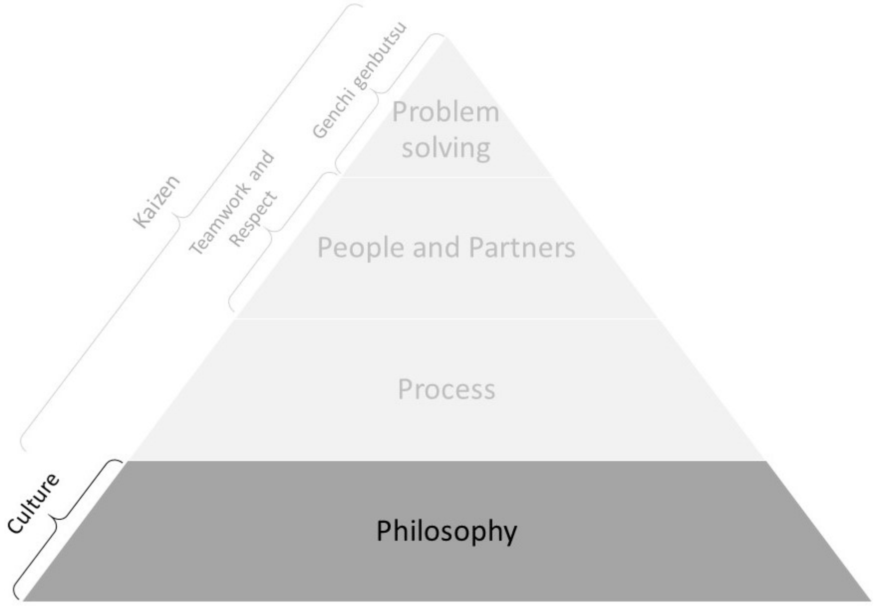

Figure 2.3: 4P model – The principle of Philosophy and the culture is the basis for all other Ps.

Companies around the world manage to implement a workable Lean strategy based program due to the extent of theory and implementation strategies that exists (Hutchins, 2008). The absolute key to success when using Lean is the culture at the company, at Toyota this is called "Toyota culture" (Liker & Hoseus, 2008). Understanding the major role culture has for Lean is essential. *Company culture* is defined as "*An intangible system of values, collective personality, and beliefs shared by people in an organisation: the company's collective identity and meaning, often described to outsiders as 'the way we do things around here'*" (Doyle, 2016). Companies like DSC should investigate further and, if needed, make cultural changes to ease and succeed in a Lean implementation.

The Lean strategy also involves professional training in many areas where the employees undergoes training in their home department. This training is executed by the leaders at each department (Liker & Convis, 2011). The training usually takes years to perform and is called *shu-ha-ri.* The *shu-ha-ri* cycle is a learning cycle that contains of three steps. In the first stage, the s*hu* cycle which means "to protect", the student is learning the fundamentals by repeatedly imitating the tasks performed. The student is being watched carefully and in a sense protected by the teacher from failure. In the second stage, the *ha* cycle which means "to break away", the student has more freedom to apply the rules more creatively but still follows the standards. The student is practicing more unsupervised here. The last stage is called the *ri* cycle which means "freedom to create". In this stage, the student no longer thinks about his or her behaviour consciously and the actions come naturally. The student can now develop his or her own understandings and is free to develop what is learned in previous stages (Liker & Convis, 2011).

The *sensei*, which is translated to "master", is allowed to provide answers to the student only in the first stage, the *shu* cycle. For the next two stages, the role of the *sensei* changes to asking questions instead, for reflection purpose. Here, the *sensei* wants the worker to reflect and think about the problem. This is called *hansei*, which translates to "reflection". At Toyota, the *hansei* phase is key to self-development. It is the process of reflecting back in time and think about what went well and what did not and how one can improve for future purpose (Liker & Convis, 2011). Figure 2.4 illustrates how the learning process of *shu-ha-ri* and *hansei* is linked together.

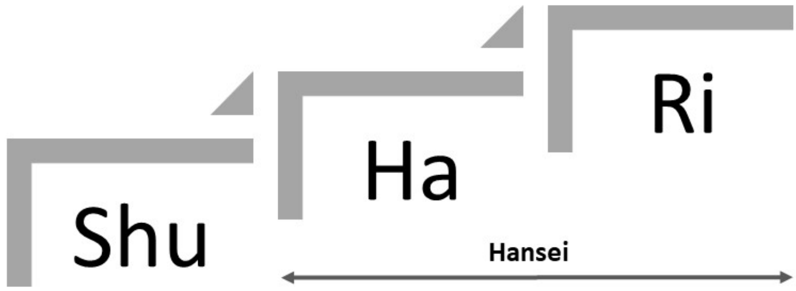

Figure 2.4: The different stages of shu-ha-ri learning cycle and where hansei occurs.

In other words, the *sensei* will try to guide the worker to think for himself rather than providing right answers. This way of guiding and coaching has proven to be an effective way of leading at Toyota (Liker & Convis, 2011). For the company DSC, this leadership philosophy can be of benefit since the workers will not see the manager as a boss but more of a "coaching friend" who stimulates the curious mind by not providing answers directly. Changing the view of how the managers or *senseis* are seen can be a major part of an organisational cultural change at DSC.

2.1.2 COMMUNICATION

Communication can have different definitions but in this thesis, communication will be defined as the transfer of information from sender to receiver under the condition that the receiver understands the information. If the communication is seen as a process, which indicates that the communication is dynamic and continuously changing, it consists of four elements; a sender, a receiver, a message and feedback. The element of feedback is crucial to ensure that the sender and receiver has the same perception of the information and it is the key for successful communication (Spaho, 2012). Communication is crucial for a successful organisation, according to Spaho (2012) bad communication between the hierarchical levels, i.e. top-down communication, can lead to conflicts inside the company which in turn hinders the company to not reach its strategic goals.

Liker & Hoseus (2008) argue that communication is a fragile tool, but Toyota has done their best to make it more robust. Toyota is very exact about communicating their current status at the company with all members and suppliers. This so that all can share the same goal and work in the same direction simultaneously. The communication is also important in bad times. The workers will be informed about the situation and be prepared when the "crash" hits or when other changes has to be done. This sort of communication is called top-down communication. The top-down communication is done mainly through face-to-face on-the-floor standing meetings. These meetings are very efficient and all objectives are accomplished. They are exactly 30 minutes long, starts and ends on the exact minute. One other way to reach the workers, where a meeting is not suitable nor possible, is through TV screens located in office and break areas (Liker & Hoseus, 2008). This is a type of written information internally in the company (Spaho, 2012). This way all co-workers gets the same information and misinterpretation is avoided (Liker & Hoseus, 2008).

The way Toyota communicate differs from how other companies are communicating. Many companies' claims that they also are sharing their information with the workers, which they most certainly are but not as frequently, accurately and long-term as Toyota does. Other companies are also hiding information to protect their employees from bad news. The problem here is that many times this way of thinking is causing more damage than good, even though the intention is good (Liker & Hoseus, 2008). One thing to not neglect is the structure of a company and its impact on the communication – low structure has faster communication and more punctual compared to high structural companies (Spaho, 2012).

Communication within an organisation can be done in different directions; top-down, bottom-up, horizontal and diagonal (Spaho, 2012). In Lean, top-down communication can be seen in the catch-ball process, which will be explored in section 2.1.3, while horizontal communication can be seen in the *yokoten* process, see section 2.1.4. In addition to this, communication can be done in different ways; written, oral and nonverbal communication (Spaho, 2012). This thesis will only consider written and oral communication since nonverbal communication requires interpretation. Oral communication can be both informal and formal communication. Informal communication is random conversations between employees or hearsays, such as rumours, while formal communication are official meetings in the company (Spaho, 2012). This thesis will cover oral communication in formal form due to its scope and purpose.

Meetings can have different purposes depending on their type. Creative meetings aim for development and encourages the participants to present their thoughts, while decision making meetings are aiming to make final decisions. Meetings, independent on their type, are recommended to be as productive as possible, otherwise people can feel that they are wasting their time (Spaho, 2012). Spaho (2012) gives suggestions on how to have a productive meeting; have a clear reason for the meeting, have a clear goal with the meeting, make sure all participants are aware of the meeting rules, chose a good environment that fits the purpose of the meeting, and take minutes which can be revisited after the meeting.

This theory about communication can benefit any company and DSC is no exception. This since communication always have the potential to improve and should be improved to minimize any misunderstandings (Liker & Hoseus, 2008). For the sake of this project, communication will be a radical foundation to have an efficient and exact problem solving procedure.

2.1.3 CATCH-BALL PROCESS

Information flow is one of the main cores in Lean practices and one helpful tool when communicating is the catch-ball process. The catch-ball process is built on simple principles which provides information and feedback for the whole process (Liker & Convis, 2011). Through meetings and interactions, the higher management are seeking opinions from next level junior managers and employees regarding setting goals. The feedback provided should mainly be in terms of if the goals are achievable or not (Liker & Convis, 2011). Figure 2.5 illustrates how the catch-ball process is operated.

Figure 2.5: Illustration of communication and the catch-ball process.

Western companies typically work differently. In Western companies do each department have their own targets and goals which other departments are not aware of. Since the targets and goals are being created in each department, the information that exists does not reach other departments. Instead, each department is reporting to their manager who reports higher up. The information flow is therefore coming from below and not from the top. Due to this, each department in the company is working “alone”, almost like sub-companies within the company. Top-down communication is also used but not for “smaller” projects or targets. This communication can for instance contain within which economy framework the targets are set (Liker & Convis, 2011).

DSC is a company in the western world and follows most of the other western companies by not applying the catch-ball process. If considering an information flow like catch-ball for instance, one can strengthen the communication across the company but also the top-down communication if desired.

2.1.4 YOKOTEN

Communication across the company, horizontally, is called *yokoten* (Soltero & Boutier, 2012). The term is translated as “across everywhere” by Liker and Convis (2011) and as “learn from” by Liker and Hoseus (2008). It is a powerful tool due to information flow that will be shared directly across the corporation, meaning the employees do not have to wait until the information reaches higher levels of management to then be sent back down again but to another department. *Yokoten* is also used when solving problems. This means that one department can be inspired from another department and how they are solving problems (Soltero & Boutier, 2012).

Yokoten will be of relevance for DSC due to the fact that information travels quicker which can improve the lead time for the problem solving procedure regarding TED. Also, this way the communication will not be misinterpreted as much as it normally would (Hutchins, 2008).

2.1.5 KAIZEN

Kaizen is a practices that overlaps three of the fours Ps in the 4P model, this can be seen in Figure 2.6.

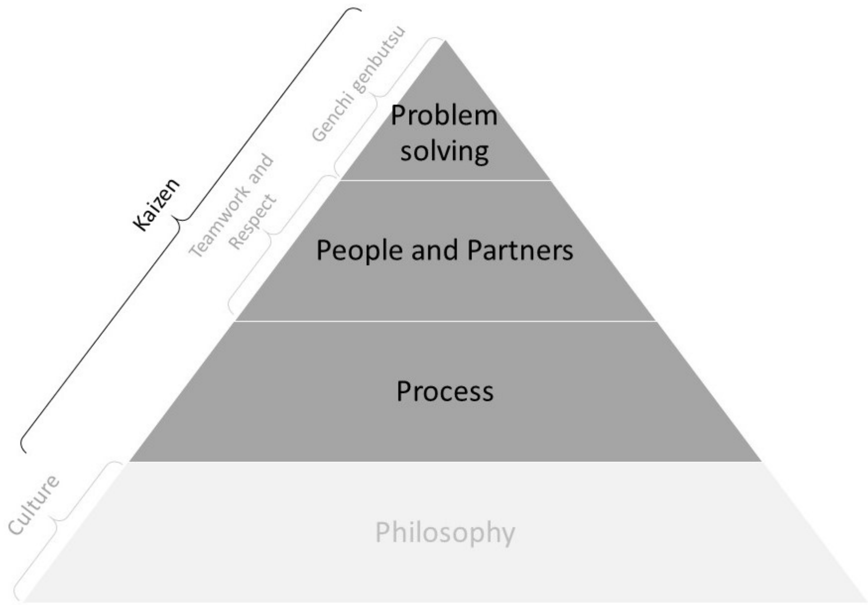

Figure 2.6: Kaizen is involved in three Ps: problem solving, people and partners & process.

Within Toyota culture, continuous improvements are called *kaizen*. The concept of *kaizen*, which is an integrated part of leadership at Toyota, has big value. Basically, it is a way of always improving the business operations continuously and always driving for innovation and evolution (Liker & Hoseus, 2008). According to Kato & Smalley (2011), one key concept of *kaizen* is that *kaizen* should focus initially on improvements that are method-based to the way things currently are performed, i.e. improving the methods rather than improving the products. The purpose of this is because improvement of methods and processes are easier to execute. Improvement of products usually involved design changes which requires a lot of effort and time (Kato & Smalley, 2011).

2.1.6 TEAMWORK AND RESPECT

Teamwork and respect is part of People and Partners in the 4P model, as can be seen in Figure 2.7.

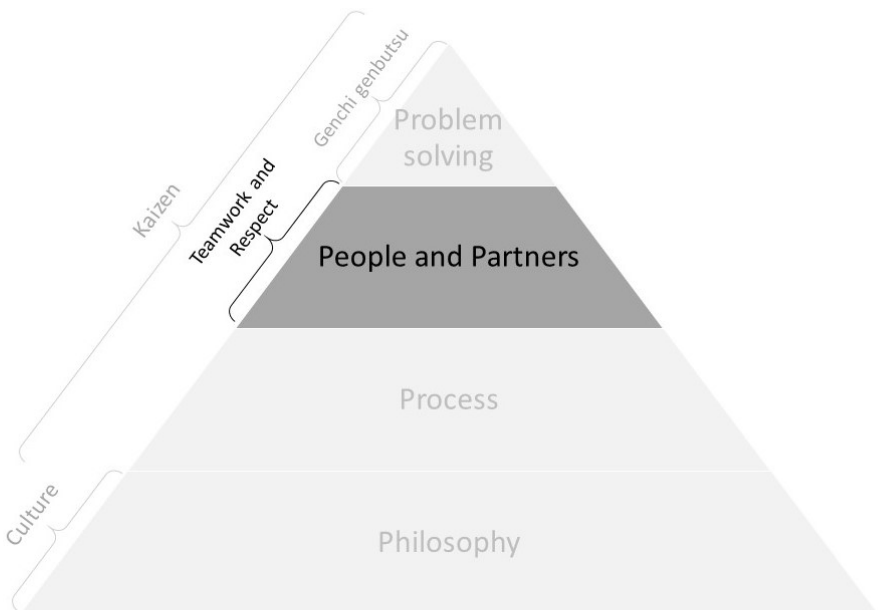

Figure 2.7: Teamwork and respect is vital in the principle regarding people and partners.

In Japan, the culture of problem solving is built around teams. When Toyota first started, they discovered the power of teams and what they can achieve together, rather than working alone (Liker & Hoseus, 2008). The teams strengthen and empower each other and are essential to Toyota and Lean. A team can be defined as two or more employees with cross-competence, so called horizontal teams, who regularly interact to peruse common goals. Teamwork on the other hand can be defined as the process of people who are working together to accomplish a common goal. Teams can be both formal and informal. A formal team is a group that is officially recognized and supported by the company. An informal team is a team that is not recognized by the company and emerges from common interests and relationships among colleges (Irirna, 2016). This thesis focuses on formal teams that are recognized by the company.

The ability to work together, keep communication consistent, improve the working environment, reduce errors and keep the communication lines open is a good and classic description of what teamwork is. Teamwork has been proven to be important due to the fact that different minds come together and interact as one. The members of the team can use their knowledge pool and experience to pull for solutions (Irirna, 2016).

When using Lean, it is important to understand that Lean is not built around individual work, it is simply developed around the power of teams. Many companies are willing to implement Lean on both production- and organisational levels but is lacking understanding of the importance of teamwork. Some people might have the opinion that the effectiveness of the individual might be reduced when working in groups and for this. Toyota have highly trained leaders to keep the groups on track, but at the same time they have someone skilled to lead the group in the right direction and always add value when needed (Liker & Hoseus, 2008).

At Toyota, it is the people who is the focus in the first place, not the profits that the company make. Respect for the people means that one have respect for each other, take responsibility, trying to understand one another, build mutual trust, stimulate growth and make effort to maximize individual and team performance (Liker & Hoseus, 2008). For this project, teamwork can be of great importance when solving component related problems since the team will strengthen and empower each other.

When talking about respect for people, this includes hiring and laying off the workforce. During some periods, sales can increase and companies need to expand their workforce. The easiest way to do this is of course to hire more people. The major problem here is that this increase in sales eventually will decrease and the workforce that has been hired to help has to go. At Toyota, situations like these are treated differently due to the culture. Since respect for the people, which at Toyota means mutual respect between the employee and the company, layoffs are not an option. This is where the competence comes in. When different departments are in need of external workers, competence from other departments are used and compensated for the absence of the needed workers, so called cross-competence. Cross-competence provides great flexibility for the company (Liker & Hoseus, 2008).

Another way of solving the need of workers temporary is the use of "temporary employees" called variable workforce. This concept is used all over the globe, but due to the Toyota culture, these workers are treated differently than the typical temporary employee (Liker & Hoseus, 2008). The company is putting a lot of effort into including these workers to be a part of the "team", meaning the core values on the shop floor like respect for the people and *kaizen* also applies to temporary employees. Using strategies like these, over-hiring can be avoided (Liker & Hoseus, 2008).

The theory described in this section is relevant due to the fact that one of the research question in this project is to identify the extent of application of the Lean practices and cross-competence is one of them.

2.1.7 STANDARDISED WORK

Standardised work lies the ground for the right Processes, and the processes is a part of the 4P model as can be seen in Figure 2.8.

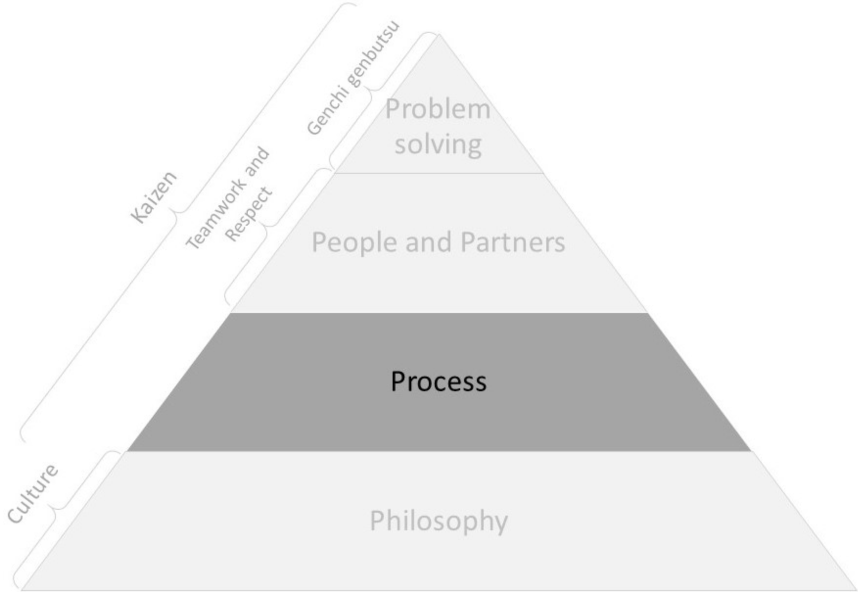

Figure 2.8: The principle of having right processes is achieved through having standardised work.

Standardised work is another main practice of Lean and a must if wanting to implement Lean. Standardised work is the foundation for the currently right processes. The basics behind it is simple: try to standardise all suitable tasks so that the procedure of them is the most efficient one. The work procedures are usually written as high detailed descriptions that are simple and quick to understand. Standardised work is a tool to maintain quality, productivity and safety at high levels (Emiliani, 2008).

According to Toyota and the Lean philosophy, the most efficient way of improvement when talking about standardised work is that the workers performing the value adding work should be used as the "engineers" (Liker & Hoseus, 2008). This due to the fact that they are the ones performing the work and the first ones who will notice if something can be improved and in what way. Standardised work can also be implemented in administrative processes. This refers mainly to how the company is working generally or how they are dealing with different problems. Having standardised ways of working is of importance since they are guiding the workers in the currently most efficient way (Emiliani, 2008). The importance of standardised work for this project is evident since the purpose of this thesis is to develop a standard for how to approach component problems.

In Table 2.1 below, an example is shown for how to solve a problem when it occurs. For this specific example, the authors have chosen to exemplify the common problem of stuck paper in printers for home use. The standard is the currently best way of solving the problem.

Table 2.1: Example of standard for when a paper is stuck in the printer

Step	**Task**
1	Open the front hatch of the printer
2	Free the cartridge inside
3	Free the paper
4	Put back cartridge inside
5	Close the front hatch of the printer
6	Press OK on display

2.1.8 JIDOKA

The act of stopping the process when defects are identified and preventing them from making it downstream the process is another foundation of Lean (Gao & Low, 2014). The Japanese term *jidoka* is used here thus the western translation of “stopping the process to build in quality”. The concept is built around the workers who has the power of stopping the process whenever they feel like needed and fix the occurred problem (Gao & Low, 2014)

2.1.9 PULL SYSTEM

The concept of a smooth production is built around a system that defines Lean, the pull system. The pull system was developed by Taiichi Ohno as a part of the Toyota Production System (Jonsson & Mattsson, 2009). Ohno wanted to create a system that minimized the inventories and the so called “work in process” (WIP) which is the products currently going through the production line. He also wanted the system to be responsive to the end demands. The pull system basically aims to create a smooth flow of materials through the production system without demanding a high inventory and WIP level, and without much communication (Jonsson & Mattsson, 2009).

The concept of the pull system was developed using inspiration from the American supermarkets where people went frequently to grocery shop, instead of doing weekly shops and store the food at home. This forced the supermarkets to refill the shelves with small batches every day as they became empty. The customers pulled the food through the supermarkets, using the simple principle of first-in-first-out (FIFO) on the shelves (Jonsson & Mattsson, 2009). This resulted in a system that is completely controlled and authorized by the consuming unit. The pull system does not start until a “start signal” (usually a card or signal) is initiated from the end consumer. This way overproduction never occurs (Jonsson & Mattsson, 2009). The pull system is visualised in Figure 2.9.

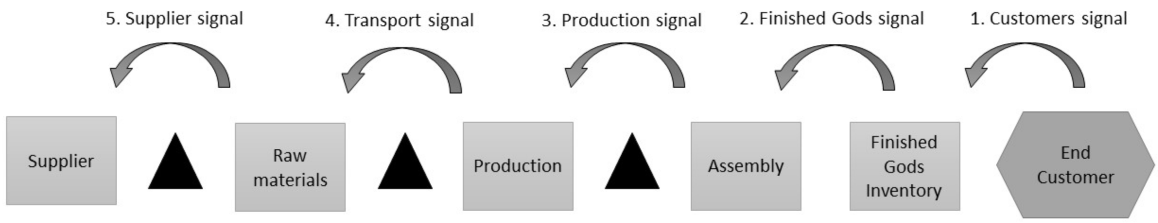

Figure 2.9: Pull system visualized, inspired by Jonsson & Mattsson (2009).

2.1.10 PUSH SYSTEM

The traditional production system that is mostly used worldwide is called push system. This system is using stocks usually between every station. The push system is not started by the end consumer like the pull system is. Here it is usually the company which decides when to start the line, usually depending on the material supply. If there is material to work with, the line starts. Due to this, a stock is also placed after the last station, called the inventory. When the demand arises, the company can pick products from the inventory for delivery to customer. The product is therefore pushed through the whole line independent of the customer (Jonsson & Mattsson, 2009). The push system is visualised in Figure 2.10.

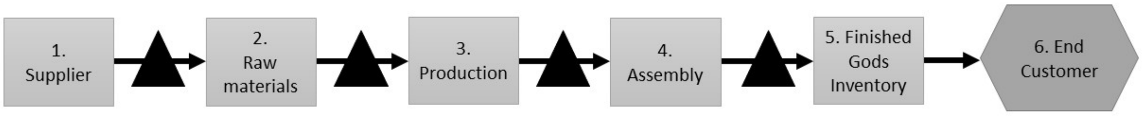

Figure 2.10: Push system visualized, inspired by Jonsson & Mattsson (2009).

2.1.11 GENCHI GENBUTSU

Genchi genbutsu is a practice that is applied when solving problems at Toyota. Problem solving is one of the Ps in the 4P model as can be seen in Figure 2.11.

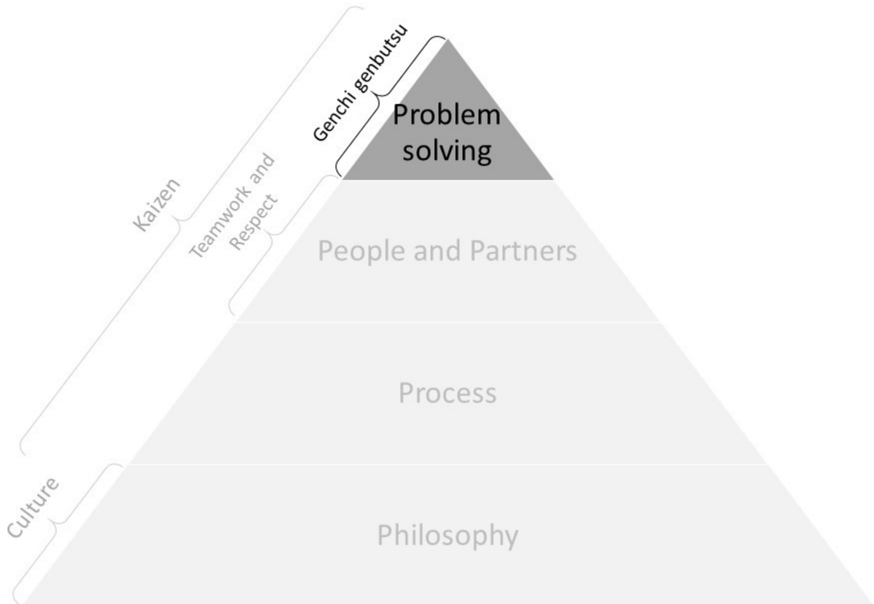

Figure 2.11: The principle of efficient problem solving is fulfilled by genchi genbutsu.

A more generic principal used by Toyota is *genchi genbutsu* which basically means “go and see”. This is a principal way of prioritising what can directly be seen on the shop floor. The managers or *sensei* encourages the workers to go to the workplace where the problem exists and deeply understand it, basically learning by doing. It is really all about building a dedicated and committed quality person by making the person deeply understand (Liker & Hoseus, 2008). This way of learning can be implemented almost everywhere where there is production. At DSC, principles like *genchi genbutsu* will be of use since the production technicians, who is supposed to solve any kind of material or component related problem, will further learn more about the product TED. *Genchi genbutsu* can also be seen as a “go and see” for administrative processes meaning it does not always have to be the shop floor where you ”go and see” to learn. It can also be the interactions between colleagues like meetings where information flows about the problem. If one does not attend the meeting for instance, the information about the problem will not reach you. Therefore, you have to attend the interactions where information can be learned. Thus is *genchi genbutsu* crucial for the technicians’ learning and their ability to solve problems.

At Toyota, investment in their workers is the biggest investment one can do (Liker & Hoseus, 2008). These investments extends over a longer period of time. Most other companies invests in projects which are shorter in time to secure fast revenues due to the western world thinking which consists of short-term thinking (Liker & Convis, 2011). At Toyota, the culture mirrors the longer investment periods long-term which eventually pays off with even bigger revenues since the workers are so committed to Toyota. This is a big part of why cross-competence at Toyota is so highly developed in comparison to the western world due to long-term thinking (Liker & Hoseus, 2008).

This way of thinking would definitely be of use for DSC due to the fact that problems should also be solved on the long-term, after it has been solved short-term.

2.2 PROBLEM SOLVING METHODS

Toyota is not only focusing on solving the problems but also seeing every problem as an opportunity for improvement (Liker & Meier, 2006). Problem solving is one of the principle categories in the Toyota production system and is one of the 4Ps, thus creating the basis to continuously improve (Liker, 2004; Liker & Hoseus, 2008). Liker (2004) explains that problem solving is done at every level of the organisation and all employees are taught how to deal with problem solving efficiently.

At the case company problem solving is a daily activity, especially when dealing with component problems. Different tools that could be used for problem solving tasks are presented in this section.

2.2.1 PLAN-DO-CHECK-ACT CYCLE

When solving problems, Deming's iterative plan-do-check-act (PDCA) cycle can be used (Liker & Hoseus, 2008; Gao & Low, 2014), see Figure 2.12. The Plan stage is where the planning is done; what to do and what to expect. In the Do stage the plan will be performed, the results from this step is studied in the Check stage. In the Check stage deviations will be identified and in the Act stage a standard can be created based on the deviations or the cycle starts over. Toyota has also added "go and see" into the PDCA cycle as something to be done in all steps. In order to truly understand the situation one has to go to the source and see. The PDCA checks should be done frequently, this to see if the plan proceeds as expected or if a countermeasure has to be taken, hence having rapid cycles (Rother, 2010). The rapid PDCA cycle provides a sense of progress and constant learning (Soltero & Boutier, 2012).

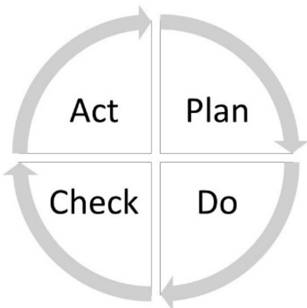

Figure 2.12: Illustration of Deming's iterative plan-do-check-act cycle.

2.2.2 A3 REPORTS

A3 reports are used for status reports, proposals and problem solving activities (Weber, 2010). The focus in this thesis will be on the usage of A3 reports for problem solving activities.

When adapting an A3 report, knowledge will be generated and the person doing it will learn (Shook, 2009). The report is named after the paper sheet size and its content varies depending on its application (Chakravorty, 2009; Weber, 2010), but the common ground is that the A3 tells a story of the approached problem. The goal of an A3 is to create a transparent problem solving process and create an organisation of thinking problem solvers (Shook, 2009). An A3 does often have seven different sections: background; current state; goals and targets; root-cause analysis; action items and proposed implementation plan; countermeasures; and follow up (Weber, 2010). The seven different sections add up in telling a PDCA story on an A3 paper (Weber, 2010; Matthews, 2001). Step 1-4 is the Plan-stage, step 5 is the Do-stage, step 6 is the Check-stage and step 7 is the Act-stage in Figure 2.13.

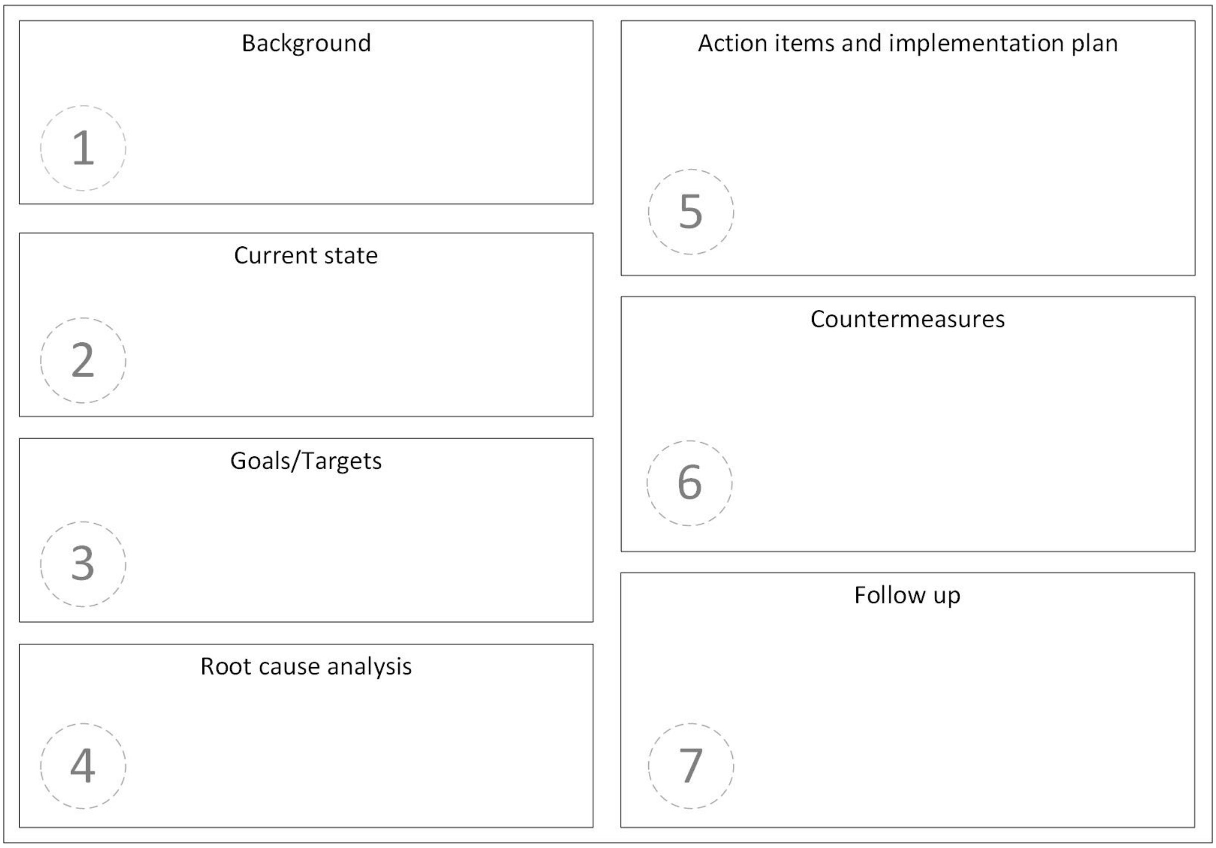

Figure 2.13: A simplified A3-report, where the left side is the plan-stage and the right side is the do-, check- and act-stage in Deming's PDCA-cycle.

2.2.3 5-WHY

The purpose of a 5-why investigation is to find the root-cause and always identify the reason for every cause (Andersen & Fagerhaug, 2006). The key concept is to question "why?" whenever a cause has been identified in order to understand if the cause is a symptom or a root-cause. When the question cannot be answered the root-cause is found (Andersen & Fagerhaug, 2006).

One example for 5-why application could be the case where a screw cannot pass through a threaded hole.

- *Why* cannot the screw pass the threaded hole?
  - There are material left in the thread from the manufacturing of the component.
- *Why* is there material left?
  - The supplying manufacturer delivered it like that.
- *Why* did they deliver the component like that?
  - The supplier followed the requirements from our drawings.

The conclusion is that our own drawings do not state the needed requirements from our own point of view.

2.2.4 Problem solving kata

Soltero & Boutier (2012) are stating that Toyota gives their employees the skills to continuously improve. These skills are what is called *kata*, which means "form", thus the performance of a structured routing (Soltero & Boutier, 2012; Rother, 2010). A *kata* is the more detailed version of a principle, i.e. *kata* tells how to do something (Rother, 2010). There are seven *katas*, improvement *kata*; nested job instruction *kata*; coaching *kata*; problem solving *kata*; job relations *kata*; job safety *kata*; and job methods *kata* (Soltero & Boutier, 2012). The focus in this section will be on the problem solving *kata*.

The problem solving *kata* is an extended version of the PDCA cycle (Soltero & Boutier, 2012). The problem solving *kata* is a five step process, described below and adapted from Solero & Boutier (2012):

1. Pick up the problem: problem consciousness
    - Identify the problem that is a priority
2. Grasp the situation (go and see)
    - Clarify the problem
    - What should be happening?
    - What is actually happening?
    - Break the problem into individual problems if necessary
    - If necessary, use a temporary measure to contain the abnormal occurrence until the root-cause can be addressed
    - Locate the point of cause of the problem. Do not go into cause investigation until you find the point of cause
    - Grasp the tendency of the abnormal occurrence at the point of cause
3. Investigate causes
    - Identify and confirm the direct cause of the abnormal occurrence
    - Conduct a 5-why investigation to build a chain of cause-and-effect relationships to the root-cause
    - Stop at the root-cause that must be addressed to prevent recurrence
4. Develop and test countermeasures
    - Take one specific action to address the root-cause
    - Try to change only one factor at a time so you can see a correlation
5. Follow up
    - Monitor and confirm results
    - Standardise successful countermeasure
    - Reflect: what did we learn during the problem-solving process?

2.3 Value stream mapping

The primary goal of Lean production is to reduce the wastes in processes and improve material flow (King & King, 2015; Liker & Meier, 2006). One way to help achieve this is to use a value stream map (VSM) (King & King, 2015). VSM is originally used in production processes where the focus is on the flow through the value stream, i.e. the system of all processes that add value to a product or product family, instead of the isolated processes (Liker & Meier, 2006; Rother & Shook, 1999). A value stream is defined as all actions required to bring a product through its main flows (Rother & Shook, 1999). The value stream represents how value is added to the product or service from the customer's perspective, rather than how the process is visualised internally in the organisation (Martin & Osterling, 2014; Locher & Keyte, 2016). VSM creates a holistic systems thinking due to the understanding of interconnections within the organisation, therefore collaborative work is enhanced, decisions are made better and sub optimization is avoided. VSM provides clarity by visualising and simplifying how the process actually works at a macro level, and from this it is clearer for the organisation in how to meet the demand of the customer (Martin & Osterling, 2014). In addition to this, the VSM does point to the problems within a process and helps to guide the Lean transformation of it (Locher & Keyte, 2016).

2.3.1 VALUE STREAM MAPPING FOR ADMINISTRATIVE PROCESSES

Liker & Meier (2006) mentions that VSM can be applied on administrative processes as well as production processes. Locher & Keyte (2016) states that VSM can be applied throughout an enterprise, thus be applied on nonproduction areas such as problem solving. In a nonproduction area is it often hard to apply Lean principles such as pull, continuous flow, takt and levelling (Locher & Keyte, 2016). Locher & Keyte (2016) also mentions that the actual material flow in an administrative process is the flow of data that will end up in a service.

A VSM is a common language for organising quantitative and qualitative data about processes (Rother & Shook, 1999). Typical process data that are gathered during the current state can be seen in Table 2.2.

Table 2.2: Common metrics used in a value stream map (Rother & Shook, 1999).

Metric	**Description**
Cycle time (C/T)	The time period between two products being finished by a process
Process time (P/T)	The time is takes to complete a process
Value-added time (VA)	The time that it takes to add value to the product or service from the customer’s perspective
Lead time (L/T)	The time it takes for a part to go through a whole value stream or a process, from beginning to end
Changeover time (C/O)	The time it takes to prepare a machine to produce a new type of product

When mapping a process predefined figures are used (Rother & Shook, 1999). Some of these figures can be seen in Figure 2.14 below.

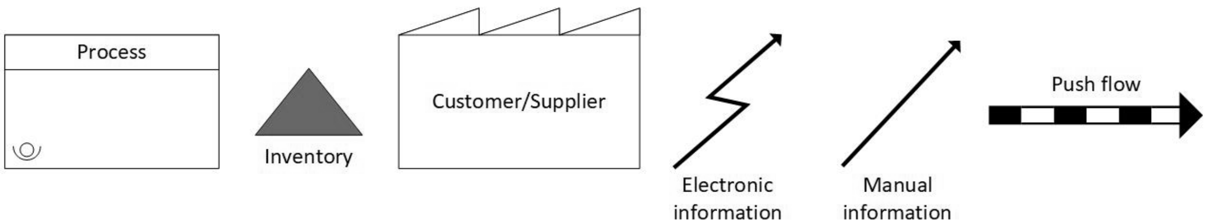

Figure 2.14: Examples of figures used in a value steam map.

Below the figures in the map, a timeline is drawn where the lead times and process times are written and visualized (Rother & Shook, 1999). A timeline can be seen in Figure 2.15 below.

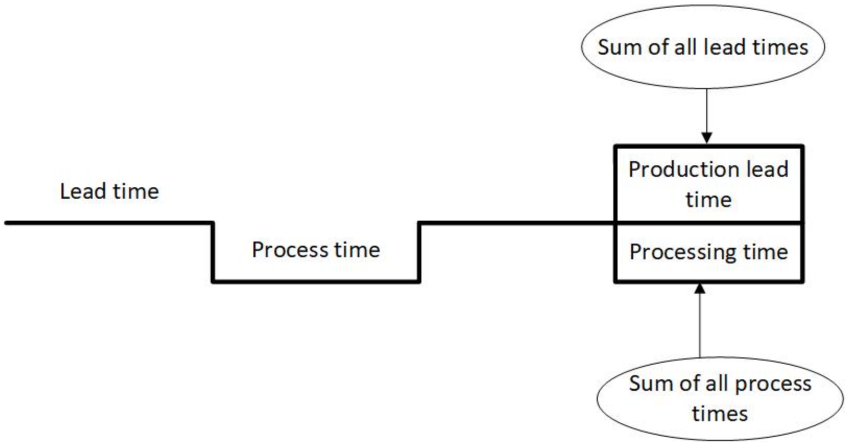

Figure 2.15: Timeline in a valuse stream map.

The aim with a VSM is to achieve a Lean value stream. A Lean value stream is achieved when a process only produce exactly the part needed and exactly when the part is needed, that when achieved creates a continuous flow. In a continuous flow, the inventory is decreased and the parts will have a reduced lead time. When eliminating inventory, a pull-flow should be achieved between the affected processes and the WIP will be kept at a minimum (Rother & Shook, 1999).

When mapping the current state for an office process the process metrics has to be selected, and many of the metrics from Table 2.2 can be applied to the office process as well (Locher & Keyte, 2016). Amaral & Forcellini (2016) has performed a VSM on the process of patent development and filing in Brazil, and the metrics used here where process time, lead time and completeness & accuracy. Process time and lead time is defined same as for production processes, i.e. the time it takes to finish a task and for how long the part is on a specific place in the process (Locher & Keyte, 2016). Completeness & accuracy is describing how often the recipient receives information that is complete and accurate (Locher & Keyte, 2016). In the case of patent development and filing there are many inventories that store information for long periods of time (Amaral & Forcellini, 2016). The inventories are a symptom of a lack of flow and is measured the same way as for production processes (Locher & Keyte, 2016). Other metrics could be changeover time and reliability. The changeover time is harder to define in an office process, but Locher & Keyte (2016) give examples of going to the printer, change paper settings and then back to the desk, or documentation has to be retrieved from a central file before the work can begin. Reliability, on the other hand, is easier to define for an administrative process since it is the time an equipment is available when needed (Locher & Keyte, 2016).

Eight different wastes have been identified in Lean production processes: overproduction; inventory; waiting; over processing; defects; movement; transportation; and underutilized people (Liker, 2004). Locher & Keyte (2016) have suggested how these occur in an office process, see Table 2.3.

Table 2.3: Eight wastes translated into an office environment (Locher & Keyte, 2004).

Waste category	**Office example**
Overproduction	Printing out paperwork before it is needed, processing paperwork before the next person is ready for it.
Inventory	Filled-in boxes (electronic and paper), office supplies, sales literature, batch processing transactions and reports.
Waiting	System downtime, system response time, approvals from others, information from customers/suppliers.
Over processing	Re-entering data, extra copies, unnecessary or excessive reports, cost accounting, labour reporting, budget processes.

Defects	Order entry errors, design errors and engineering change orders, invoice errors, employee turnover.
Movement	Walking to/from copier, other offices.
Transportation	Excessive email attachments, multiple hand-offs, multiple approvals.
Underutilized people	Limited employee authority and responsibility for basic tasks, management command and control, inadequate business tools available.

In addition to these eight wastes, three more are presented when identifying waste within a product development process (Bauch, 2004), see Table 2.4.

Table 2.4: Three additional wastes identified within product development process (Bauch, 2004).

Waste category	**Product development example**
Reinvention	Poor design reuse, poor knowledge reuse
Lack of discipline	Unclear goals and objectives, unclear responsibilities, poor schedule discipline
Limited IT resources	Poor compatibility and capability and low availability

The purpose of a VSM is to truly understand the processes in order to create a future state that is more effective than the current state (Liker & Meier, 2006). When implementing the future state, wastes should be eliminated and only produce when a customer needs it (Rother & Shook, 1999). The future state for a production process is developed on the basis from answering eight questions by Rother & Shook (1999) on the left side in Table 2.5. When developing the future state for an administrative process there are instead seven other questions, see right side in Table 2.5, and these questions represent the Lean concepts waste, flow, pull, levelling and management timeframe (Locher & Keyte, 2016).

Table 2.5: Future state questions for production processes (Rother & Shook, 1999) and administrative processes (Locher & Keyte, 2016).

Production processes	**Administrative processes**
What is the real customer demand? What is the takt time?	What does the customer really need?
Will we produce for direct delivery or to a finished goods stock?	Which steps create value and which generate waste?
Where can we produce in a continuous flow? Where can we reduce waste? What activities can be eliminated; combined; simplified; made in another order?	How can work flow with fewer interruptions?
Where in the flow will we plan the production (pacemaker)?	How will interruptions in the flow be controlled?
Where do we place supermarket pull systems (buffers) for regulating the flow?	How will the workload and/or activities be balanced?
How do we level the production mix?	How will we manage the new process?
In which batch size should we produce?	n/a
Which process improvements are needed (training, reductions of disturbances, quality improvements, reduction of changeover time etc.)?	What process improvements will be necessary to achieve the future state?

Further the future state questions for administrative processes will be explained.

The first question is of relevance since Lean is market driven. When the questions: who need the output; what is required and how often is it required; and when do they need it, are answered are the customer requirements gathered. The customer requirements, and the takt time, is important to understand so an appropriate management time frame can be identified. The takt time is calculated as (Locher & Keyte, 2016):

$$Takt\ time = \frac{Effective\ working\ time\ per\ time\ period}{Customer\ requirement\ during\ the\ time\ period}$$

As stated above, wastes are to be reduced within Lean (King & King, 2015; Liker & Meier, 2006) and therefore the second question is of relevance. To identify the wastes within the process the following questions are used as guidance (Locher & Keyte, 2016):

- Why are the current step being performed?
- What can the company do differently while still meeting customer needs?
- Is the order of steps creating waste? At what steps should decisions be made?
- What assumptions underlie the design of the current process?
- Are current controls and administrative guidelines appropriate?
- What knowledge and skills are truly required to perform the steps?

By eliminating wastes, the flow will be improved which validates the third question. With a smooth flow is the WIP reduced and the possibility for interruptions in the flow will decrease. There are places in the process where the flow will be interrupted, and these will be controlled. The fourth question deals with this issue. Interruptions is often types of buffers, and one example to achieve a sense of pull in a buffer is to have a FIFO system with limited space. Question three and four deals with some issues of levelling, but unlevelled processes and systems do still occur, which are dealt with the fifth question. Through a levelled workload the enterprise can be more predictable and the response to customer demands are shorter, hence a shortened lead time. Once the future state is developed through question one to five, the countermeasures of the new value stream will be decided upon in the sixth question. The reason for deciding this is to see the performance of the value stream and is often done by the team members in the value stream. Finally, in the seventh and last question, the tools and techniques for the future state can be decided upon. Typical Lean tools can be used, such as standardised work; quality detection; and cross-functional teams (Locher & Keyte, 2016).

VSM has been applied in various administrative processes, among them are clinical trials (Martinez, et al., 2016), the sales process (Barber & Tietje, 2008), payment processes (Costa, et al., 2013) and, as mentioned above, patent developing and filing (Amaral & Forcellini, 2016). When adapting VSM to the sales process, Barber & Tietje (2008) did identify various challenges, among them were:

- The variation in the process which depends on the people, circumstances and companies, hence not having a standardised nor repetitive process, therefore are they not easily measured with the stopwatch technique.
- The non-predictable interactions in the process and the simultaneous and iterative actions, which is the opposite of a manufacturing process.
- The issue of not having a specific product to follow through the value stream, but a customer specific solution.
- The unclearness of value-adding and non-value-adding activities, thus the need of redefining them depending on the setting.

In the sales process is the WIP defined as the solutions that has been partially developed but is not progressing any longer for some reason. Even though challenges were identified, is it concluded that a possibility to apply VSM to a creative process can be achieved (Barber & Tietje, 2008).

2.4 Kanban project management

There are different methodologies for agile project management and one of them is called *kanban*. *Kanban* project management was inspired by the TPS and Lean production and emphasizes just-in-time delivery (Lei, et al., 2015). *Kanban* project management eliminates waste in every step of the project by not producing something that cannot be used in the next step of the process nor produce when not having all information needed to produce. In order to visualize the process throughout the project a "card wall" used, see Figure 2.16. Each card represents a problem on the "card wall" and the card is moved along the board when different tasks are finished (Lei, et al., 2015). From this it is visualized which tasks that are in progress (Lei, et al., 2015) and where the bottlenecks are located in the process (Lei, et al., 2015; Ikonen, et al., 2011). Ikonen et al. (2011) found that visualization motivates people as well as helping in controlling the different tasks in a flexible way. Lei et al. (2015) agrees that *kanban* project management allows for flexibility. Lei et al. (2015) further argue that *kanban* project management creates a pull-scheduling of the tasks while also increasing the throughput of the process.

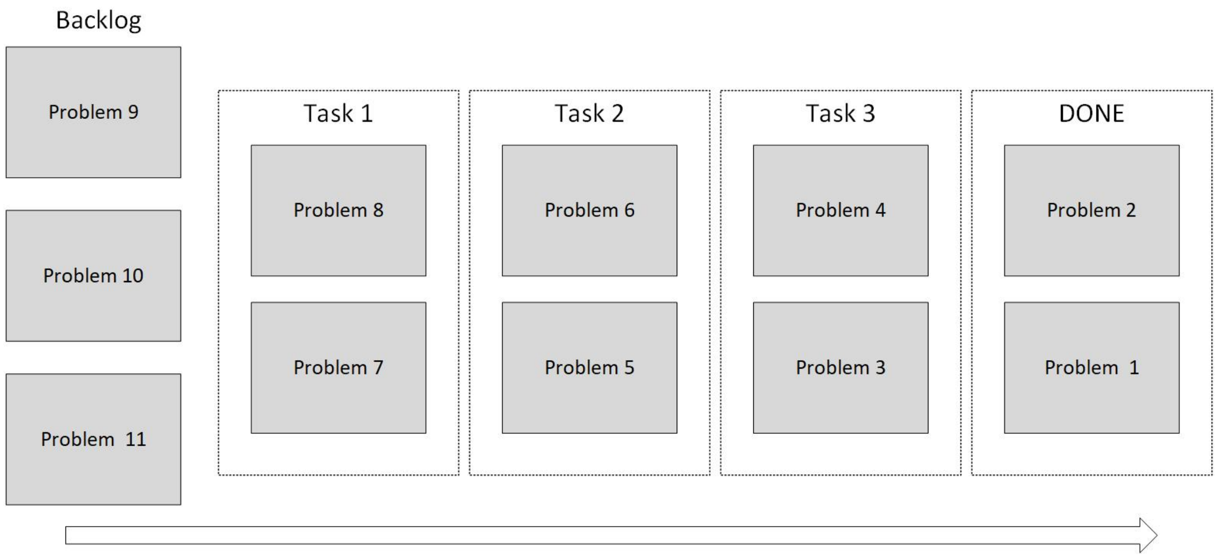

Figure 2.16: A simplified kanban card wall where the different tasks are moved as they proceed in the different steps of a process, inspired from Lei et al. (2015).

During a study of comparing *kanban* methodology to another agile project management methodology did Lei et al. (2015) found that having one of these methodologies will lead to development of successful projects. When evaluating the different methodologies did Lei et al. (2015) compare six factors: schedule; scope; budget; risk; resources; and quality, and *kanban* is found to be more effective in all factors except the budget factor. Lei et al. (2015) emphasize the advantage of using *kanban* in terms of scheduling, which was evaluated in three aspects: projects teams' awareness of project status; the project's deliverability in terms of time; and project teams' adaptability to changes. The scheduling factor has also been found to be more effective in smaller companies (less than 50 persons), this is discussed by Lei et al. (2015): at smaller companies there might be more defined roles and different skill sets in the project teams, which is claimed to be beneficial when working according to the *kanban* methodology.

2.5 SYNTHESIS OF LITERATURE INTO ANALYTICAL/CONCEPTUAL FRAMEWORK

As can be seen in Table 2.6 the aspects of this thesis is connected to Lean practices as well as other concepts such as *kanban* project management.

Table 2.6: Which practices and concepts that are conntected to which aspects of this thesis.

	Solution quality	**Organisation in problem solving procedures**	**Learning problem solving procedures**	**Effective problem solving procedures**
Shu-ha-ri			X	
Catch-ball process		X		X
Yokoten	X	X		
Kaizen		X		X
Teamwork		X		
Standardised work		X	X	X
Jidoka	X			
Pull system				X
Genchi genbutsu		X		X
PDCA cycle				X
A3 reports	X			X
5-why	X			X
Problem solving kata	X			X
VSM				X
Kanban project management		X		X

The three first aspects of the thesis, solution quality; organisation in problem solving procedures; and learning problem solving procedures, are considering aspects to be evaluated in the current problem solving procedures and will be considered when developing the new suggested problem solving procedure. The fourth and last aspect is effective problem solving procedure which relates to the development of the new suggested problem solving procedure which should be more effective than the current one.

3 METHOD

This chapter will discuss the method and tools used in this project. Furthermore, research quality and ethical considerations are discussed.

3.1 RESEARCH PROCEDURE

The research in this project had the purpose of identifying how to resolve component problems as a means to improve the production system performance. The problem solving procedure will, in this project, be treated as a standard of how to resolve component problems.

According to Zandin & Maynard (2001) the development of a standard should start with analysis and documentation of the current methods and later identifying the best method. From this, the methods can be broken down to elements and standard times can be set (Zandin & Maynard, 2001). Voss et al. (2002) set out a step-by-step framework for case studies, where the first step is to explore the setting, secondly build the theory framework to develop the research questions. After this the case study is defined, the field study is performed and the analysis can be made (Voss, et al., 2002).

Zandin & Maynard (2001) and Voss et al. (2002) laid the ground for the procedure for developing the new problem solving procedure in this project, but the general research procedure is shown below:

1. Design the study
    a. Explore on site about the setting
    b. Literature review
    c. Define the case study
    d. Define method
2. Data collection
    a. Study current procedures for solving component problems
    b. Collection of data needed for evaluation of the current state performance
3. Analysis of the data
    a. Analysis of how lean practices are applied in current problem solving procedures
    b. Identify how optimal problem solving procedure should be designed
    c. Answering research questions
4. Development of recommendation

3.2 RESEARCH STRATEGY

The choice of strategy is important to consider since it is affected by many practical issues, such as finding the right people, having access to crucial documents and meeting the deadlines (Denscombe, 2014). The research strategy affects the research ethics (Denscombe, 2014) and this is to be discussed in section 3.6. The chosen strategy for this research is a mix of a literature review and a case study.

3.2.1 LITERATURE REVIEW

The literature review in this research was seen as a traditional or narrative literature review. This type of literature review creates a body of literature from relevant studies and knowledge in the area of subject (Cronin, et al., 2008). The process of performing a literature review is to first select a relevant topic, search, gather, read and analyse the literature and then write the review (Cronin, et al., 2008). According to Denscombe (2014) a literature review does entail a search for relevant literature, a review of the found literature and a conclusion based on an objective analysis of the found literature.

To gather literature, different data bases was used such as Google Scholar, Scopus and Web of Science etcetera. Keywords searched for were related to the research questions or purpose, such as "*value stream mapping*", "*administration*", "*lean*", "*problem solving*", "*performance*", and "*production rate*" etcetera. The narrative literature review was supplemented by "snowballing", i.e. using the reference list of an interesting source to find further information (Scott, 2015).

When gathering information about Lean practices that were applied did the authors mainly searched for practices that are more organisational, e.g. *yokoten*, but also practices found in literature regarding value stream mapping for administrative processes, e.g. pull system. Lastly did the authors searched for practices that were applicable for administrative processes with some adaptations, e.g. *genchi genbutsu*.

3.2.2 CASE STUDY

The case study method is typically used for answering questions with the nature of "what", "why" and "how" (Voss, et al., 2002), which is the nature of the research questions of this project.

A case study is defined as understanding of a complex relationship between factors as they operate in a social setting (Denscombe, 2014). The purpose of a case study could range from describing or exploring to explaining or illustrating (Denscombe, 2014). In a production system case studies are common to describe the humans in arrangements of the physical elements (Voss, et al., 2002). The chosen case must have fairly distinct boundaries, otherwise it blends into other social phenomena (Denscombe, 2014). When choosing the strategy of performing a case study, it provides an in-depth study with a holistic view where the focus lies on relationships and processes (Denscombe, 2014; Voss, et al., 2002). When using the case study approach it opens up for usage of both qualitative and quantitative data and a combination of various types of methods, e.g. interviews and observations (Denscombe, 2014). A case study approach opens up for development of the research questions during the time, once more knowledge is gathered can the research questions be more specified (Voss, et al., 2002). The whole project is a case study, hence will the results be case specific and might not be applicable outside the case study. The case is represented by the case company, the specific product and the internal problem solving procedures.

3.3 DATA COLLECTIONS METHOD

During this project many different methods for collecting data were used. Among them were interviews, where qualitative data about the current processes was the focus. In addition was quantitative data analysed. All quantitative data needed was not collected by the authors, but found in the ERP system of the company or other sources available from the company, and this data will be treated as secondary data. Secondary data is data that is not collected for the research itself and thereby not collected by the authors themselves either (Doyle, 2016).

3.3.1 INTERVIEWS

In order to gather qualitative data, semi-structured interviews were conducted. Interviews can be used to map and explore complex issues, experiences and privileged information (Denscombe, 2014). The semi-structured approach does contain a list of open-ended questions, but the sequence of the questions can be altered and the interviewer has the opportunity to ask the interviewee follow-up questions (Denscombe, 2014). All interviews are performed two-to-one, i.e. two interviewers and one interviewee, but if there were times when one of the interviewers could not attend, the remaining interviewer held the interview alone. The interviews were performed in Swedish since this is the national language and due to this, it was easier for the interviewees to express their thoughts and feelings.

A total of 39 interviews were conducted and the interviewees were all invited based on their involvement in the organisation's current procedures for solving component problems. 10 interviewees being part of one of problem solving procedure GG, 7 interviewees from Andon problem solving procedure, 12 from the third problem solving procedure MM and 11 operators from the production of TED. The number of interviewees is important in order to find themes, the number of interviewees were to be more than one (Denscombe, 2014). The interviewees who agreed on being recorded where also transcribed and had an option to go through the transcription in order to further validate if wanting to. Only three interviewees choose to validate the transcription, while 35 people in total agreed on being recorded. For the interviewers who did not accept being recorded, the interviewees took notes instead. These notes were available for the interviewees to go through in order to validate them.

3.3.2 Observations

Through observation the authors could gather qualitative information about what actually happens on site (Denscombe, 2014). Denscombe (2014) emphasizes the importance of being on site for a long period of time in order to get a holistic view of the setting. Being on site also helps to identify the problems and issues in the setting (Denscombe, 2014). During the whole project were the authors working on site to capture as much information as possible about the actual processes. In addition did the authors not only observed in meetings regarding component problems, but also participated in that sense that they interfered in the solving process when the authors has ideas for solutions or proceedings.

3.3.3 Workshops

The authors conducted workshops after analysing the information from the interviews. The workshops was used to validate the authors' analysis of the interviews, and the authors' perception of the current state were either validated or disregarded. There were four workshops, where each workshop was aimed towards a specific group of interviewees. The interviewees were invited to a meeting where the authors first presented the analysis and after followed a discussion with the interviewees about uncertainties. If the authors had further questions these were asked. The latter part will be treated as a semi structured group interview. From this a wide range of answers can be channelized through the authors (Denscombe, 2014).

The information presented to the participants were conclusions drawn from the interviews, presented with a PowerPoint-presentation and the participants were encouraged to speak their mind if there were any uncertainties.

3.4 Analysis of data

There are two different types of data, qualitative and quantitative (Denscombe, 2014). Qualitative data is most of the data gathered in this project and its analysis differ compared to the quantitative data.

Qualitative data is spoken or written words and images. The images can be both produced images but also images from observation. Words and images are interpreted by the researcher and are dependent on the researcher's own experiences and knowledge (Denscombe, 2014). Qualitative data serves the mission of finding patterns, differences or divergences among the data sources (Denscombe, 2014; Voss, et al., 2002). For example, the authors can find differences regarding a subject among the interviewees in the study.

Quantitative data is numbers of any kind. Even though quantitative data seems to be objective can the researcher have an influence on in (Denscombe, 2014). This could have occurred when the authors themselves performed an empirical study with the aim of collecting vital quantitative data, such as cycle time etcetera.

3.4.1 ANALYSIS OF THE CURRENT PROBLEM SOLVING PROCEDURES

One way of analysing qualitative data was to compare theory to the answers from the interviews and the authors' observations. From this conclusions of similarities and differences could be identified. Lean practices were identified in the interviews where the authors asked questions related to different Lean practices, e.g. the question "how are you proceeding with a problem outside of the meeting?" asks if the person is going to the problem (g*enchi genbutsu*) or working in teams and if there is a standardised way of approaching problems.

Quantitative data was analysed in order to see the component problems' impact on the production system performance. The quantitative data used here was from the company's ERP system, and will therefore be treated as secondary data.

When analysing both qualitative and quantitative data the method of performing VSM was selected. A VSM is vital to perform in a Lean transformation since it highlights waste and the waste's effect on the process flow (King & King, 2015). The purpose of a VSM is to visualize the flow of material and information needed to produce a product (Rother & Shook, 1999). In this project the product will be seen as the problem solution while corresponding materials will be information added in order to find a solution.

To gather information needed in the VSM, such as cycle times, set up times etcetera, the authors performed an empirical study mapping problems that were solved in the different problem solving procedures. The mapping was based on information that were available in different documentation tools for the different problem solving procedures. If the documentation were lacking in information, assumptions were made based on information from interviews and discussions with people involved in the problem solving procedure. The focus on a VSM should be on a problem family (Rother & Shook, 1999; Locher & Keyte, 2016). The selection of a problem family can be done using a matrix (Rother & Shook, 1999; Locher & Keyte, 2016) where the different problems are placed on the Y-axis and the different tasks are on the X-axis. The problems going through the same tasks creates a family, see Figure 3.1 below.

Problem family

	Task 1	Task 2	Task 3	Task 4	Task 5	Task 6
Problem A	X	X	X	X		
Problem B	X	X	X	X		
Problem C	X	X	X	X		X
Problem D			X	X	X	
Problem E		X		X		X

Figure 3.1: A problem family matrix, problems going through same tasks acts as a family (inspired by Rother & Shook (1999)).

3.4.2 DESIGNING THE PROBLEM SOLVING PROCEDURE

When designing the future state the authors followed the seven future state questions by Locher & Keyte (2016):

1. What does the customer really need?
2. Which steps create value and which generate waste?

3. How can work flow with fewer interruptions?
4. How will interruptions in the flow be controlled?
5. How will the workload and/or activities be balanced?
6. How will we manage the new process?
7. What process improvements will be necessary to achieve the future state?

In addition to this, theory about different problem solving methods and Lean theory were used to further develop the future state into the new standard.

3.4.3 ANSWERING THE RESEARCH QUESTIONS

The research questions was answered by triangulating qualitative data from interviews, qualitative and quantitative data from the VSM and the theoretical framework. The research questions were answered in both Analysis and Discussion chapters.

3.5 RESEARCH QUALITY CONSIDERATIONS

The project was validated through a workshop where the authors presented the suggested future state problem solving procedure. Here the attendants were the ones that are to be involved in the new suggested problem solving procedure and they could speak their concerns about the suggested procedure. If the findings could be generalised outside of the case study were discussed during the project and is further discussed in the Discussion chapter of this thesis.

Voss et al. (2002) argue that vaildity can be devided into two aspects, construct and external validity. Construct vailidity is considered to be the extent to which the studied concepts are a reflection of the reality (Voss, et al., 2002). Construct validity was guarenteed by triangulating different soures of answers, which in this thesis were the information from the interviews and observations. External validity is to what extent the results can be used outside the specific case (Voss, et al., 2002). External validity was discussed in Discussion chapter, in section 7.7. Voss et al. (2002) argue that the reliability of the study is a measurement for validity, where reliability is considered to the extent that a study can be repeated and get the same results. The qualitative data gathered from interviews will differ depending on who performs the interview due to the fact that the interviews where of semi-structured form, hence not strictly following a set of questions. The mapping of the problems, based on the assumption that the same information will be available, can be repeated, the same goes for the observations. Thus, the case study can be repeated with some deviations in qualitative information.

3.6 ETHICAL CONSIDERATIONS

Denscombe (2014) argues to follow four key principles in order to care for the ethics of the research. The four key principles are (Denscombe, 2014):

- Participants' interests should be protected
- Participation should be voluntary and based on informed consent
- Authors should operate in an open and honest manner with respect to the investigation
- Research should comply with the laws of the land

These key principles are fulfilled by the authors by informing the participants about the aims with the research, that they as interviewees are anonymous and voluntary to participate. If the interviewees had further questions the authors welcomed them and answered them directly on the spot in order to be transparent with the interviewees. If the interviewees were not willing to answer a question due to personal matter, or other reason, this was respected by the authors. Information containing confidential or personal information were filtered by the authors before published. Furthermore, the laws of the land were followed since the topic of the research is not a sensitive matter nor the information gathered. This is also ensured by the authors having a signed contract with the company to not only follow the law but also to follow the company's code of conduct.

3.6.1 SUSTAINABILITY CONSIDERATIONS

Sustainable development was at first defined as development that are not only meeting the needs of the present but also provides the ability of meeting the needs of the future. Later sustainable development has been divided into three tracks: economic, environmental and social (Berlin & Adams, 2017; Portney, 2015). Portney (2015) argue that sustainability cannot be achieved unless all three tracks are considered and fulfilled. Berlin & Adams (2017) state different things to consider when talking about the different tracks of sustainability:

- Economic sustainability: meeting market demands, profitability, business growth
- Environmental sustainability: environmental resources, planet
- Social sustainability: social justice, equity and equal opportunities

When talking about manufacturing sustainability Mahmood et al. (2015) have translated the overall equipment effectiveness factors – availability, performance and quality – to different sustainability factors. These can be seen below (Mahmood, et al., 2015):

- Economic: downtime cost reduction, labour efficiency, scrap and rework cost minimization
- Environmental: scrap elimination, material utilization, energy efficiency
- Social: safety and health, labour efficiency, stakeholder satisfaction

These three tracks of sustainability were considered by the authors in the development of the new problem solving procedure presented to DSC. The economic sustainability was considered in the sense that the new problem solving procedure should be more resource and labour efficient and reduce the problem solving lead time. Environmental sustainability was considered by removing the wastes found in the current problem solving procedures and from this should scrap be minimized while material and energy should be used more efficient. The social sustainability was considered by increasing the labour efficiency in the new problem solving procedure and by reducing the problem solving lead time the stakeholder satisfaction will increase since production system performance increases.

4 CURRENT STATE

In this chapter the current state of the problem solving procedures at the case company is presented. Firstly presented is the observatory data that laid ground for the interviews. Furthermore is the value stream map for the current state presented.

4.1 OBSERVATORY DATA

At DSC the component problems are found either at the arrival control that is done on every component before approving it for assembly or during assembly of the product TED. Typical component problems are too long screws, scratches on surfaces or misplaced holes. Once the problem is identified a non-conformance report (NCR) is written by the operator electronically in the ERP software. The operator then sends an e-mail to a responsible production technician, this e-mail consists of the individual NCR-number and its purpose is to communicate that an NCR has been written. This NCR is now available for the production technicians to act upon. The authors have represented this process with a flowchart. The basic flowchart shapes and what they represent in Figure 4.1.

Figure 4.1: Basic shapes in a flowchart.

See Figure 4.2 for a flowchart of how the operator acts when finding a component problem.

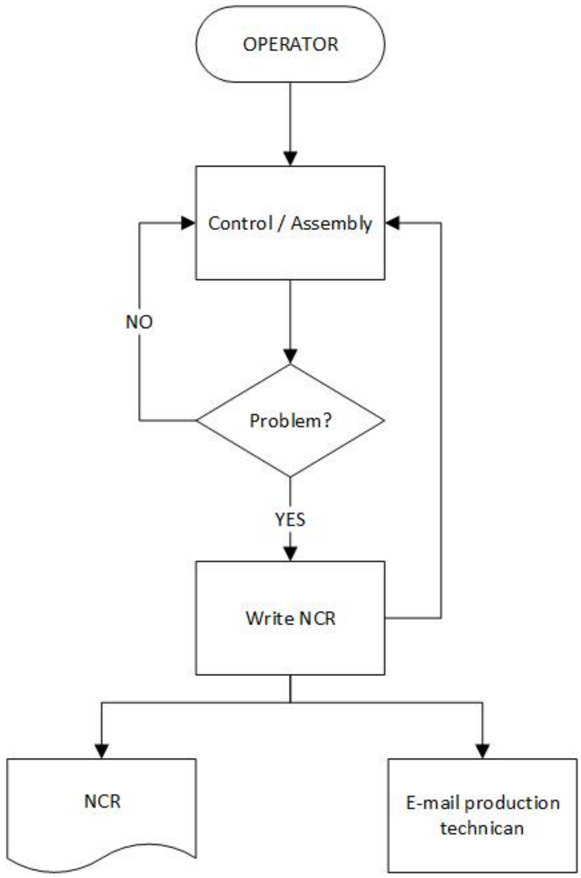

Figure 4.2: Flowchart of how the operator acts when a component problem is found.

The production technicians, working with the manufacturing of product TED, have the choice of acting upon the NCR or leaving it in a “buffer”. When acting upon the NCR, the production technician has the choice of lifting the problem to one out of three problem solving procedures, see Figure 4.3 for a flowchart of the process. The current problem solving procedures and their members are:

- Guldgruvan (the gold mine), further abbreviated to GG, which members are the managers of all manufacturing units on site and production planners.
- Andon which members are mechanical engineering designers.
- Materialmötet (the material meeting), further abbreviated to MM, which members are all connected to product TED, meaning the project leader, production technicians, purchasers, material planners, quality manager, mechanical engineering designer and system owner.

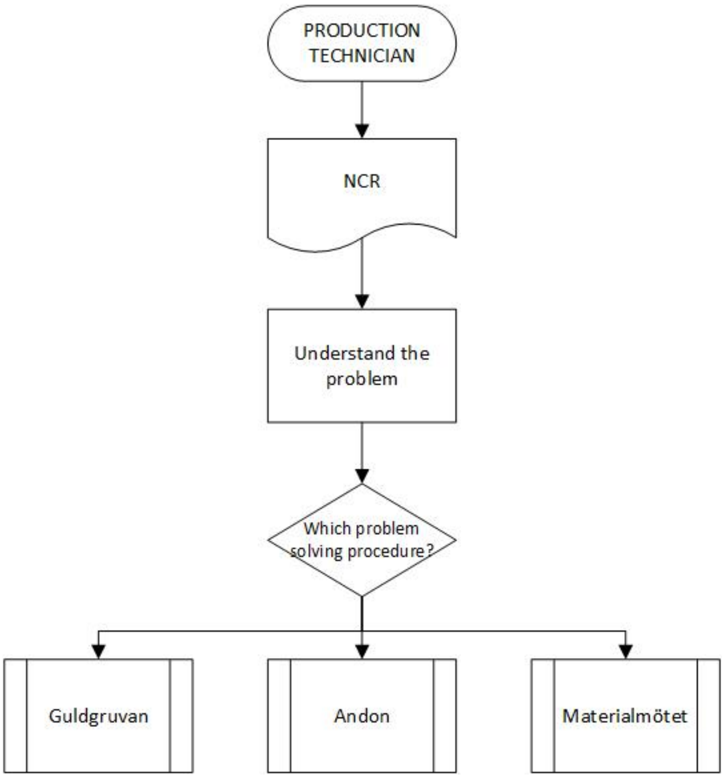

Figure 4.3: Flowchart of how the production technicans act when an NCR is decided to act upon.

The choice of which procedure to use is not based on any specific guidelines or rules, but only on what the technician finds appropriate for that particular problem. The decisions can be based on when meetings for the different procedures are held or if any particular person is attending one of the meetings.

4.1.1 NON-CONFORMANCE REPORTS

When the operators are filing an NCR it is in a software where different information boxes are to be filled in. A visualization can be seen in Figure 4.4, where the grey box named “Details” is including more boxes than showed, but these boxes are not for the operators to fill in. Before even getting to this page one has to go through six steps. These steps are a way of selecting the production order affected by the problem and where in the process the problem is found.

Figure 4.4: What to fill in when writing an NCR as an operator. There are additional boxes, but they are not to be filled in by the operator.

Further are the different sections described and what they are to contain.

1. Non-conformance code: there are pre-defined codes for different types of problems and which components they are relating to. This is a number and there are guides in what problem should have which codes available for the operators.
2. Description: short description about the problem. Here there are no more guidelines in what should be included to describe the problem.
3. Responsible person ID: each sub-product has its own production technician as a responsible person. Here the operator should select the right responsible person. From this will the NCR occur in the production technician's inbox.
4. Root-cause ID: here the operator should select one of the five root-causes: engineering; production; supplier; not established; not reported; and other. Here there are no guidelines in what root-cause to choose.

5. Time spent on NCR (h): the operator should file how much time they have spent on this specific problem.
6. Additional information: the operators have guidelines in what to fill in here, it should be the serial numbers for the specific component and, if applicable, the individual number of TED the component is tied to.

After these steps the NCR should be activated and set to "Released" so steps of actions can be added. If the operator has performed some actions to the problem they can report them, and later on close the NCR if they consider the problem to be fixed by the actions. Once the NCR is closed is it no longer available for the production technicians.

During 2017 the whole department, which TED is a part of, wrote 719 NCRs and the production technicians spent 1621 hours on solving these. On average they spent 2 hours and 15 minutes per NCR. During the three reported months of 2018 have 181 NCRs been reported and the technicians have spent 352 hours on solving these. The average solving time, during 2018, has been 1 hour and 57 minutes. For a summary see Table 4.1.

Table 4.1: Summary of average number of NCRs and the time spent on solving NCRs during 2017 and 2018.

	NCRs / month	Time spent /month	Time / NCR
2017	59.9	135 h	2.25 h
2018	60.3	117 h	1.95 h

When writing NCRs the operators should decide upon the root-cause of the faulty problem, the different categories to decide upon are engineering; production; supplier; not established; not reported; and other. The dominant category is "not established" with an average of 20.9 NCRs per month during 2017 and 22.3 NCRs per month during 2018. The production technicians spent most time on NCRs with the root-cause "not established" in both 2017 and 2018, 45 hours per month respective 46 hours per month. The longest time spent per NCR were on the category "Other" in 2017 (3.5 h/NCR), while in 2018 it is the categories "Other" (1.7 h/NCR), "Supplier" (1.7 h/NCR) and "Not established" (1.7 h/NCR). A summary of the average number of NCRs per month, average time spent per month and average time spent per NCR for the years 2017 and 2018 for the different categories can be found in Table 4.2, Table 4.3, Table 4.4, Table 4.5, Table 4.6 and Table 4.7.

Table 4.2: Summary of NCRs with the root-cause category "Engineering" during 2017 and 2018.

	Engineering		
	NCRs / month	Time spent /month	Time / NCR
2017	4.4	13.6 h	1.15 h
2018	1.5	1.5 h	1 h

Table 4.3: Summary of NCRs with the root-cause category "Production" during 2017 and 2018.

	Production		
	NCRs / month	Time spent /month	Time / NCR
2017	9.3	15.3 h	1.6 h
2018	8	13 h	1.6 h

Table 4.4: Summary of NCRs with the root-cause category "Supplier" during 2017 and 2018.

Supplier	NCRs / month	Time spent /month	Time / NCR
2017	15	33.6 h	2.2 h
2018	18.3	31.7 h	1.7 h

Table 4.5: Summary of NCRs with the root-cause category "Not established" during 2017 and 2018.

Not established	NCRs / month	Time spent /month	Time / NCR
2017	20.9	45.2 h	2.2 h
2018	18.3	31.7 h	1.7 h

Table 4.6: Summary of NCRs with the root-cause category "Not reported" during 2017 and 2018.

Not reported	NCRs / month	Time spent /month	Time / NCR
2017	4.6	5.25 h	1.2 h
2018	8	3 h	0.4 h

Table 4.7: Summary of NCRs with the root-cause category "Other" during 2017 and 2018.

Other	NCRs / month	Time spent /month	Time / NCR
2017	5.7	20 h	3.5 h
2018	2.7	4.7 h	1.7 h

4.1.2 Organisational structure

The product TED is part of a product family that is produced on site. It has its own production unit and is, more or less, not connected to the other product families on site. The people at DSC therefore sees TED's product family as a factory within the factory, which does not always follow the organisational processes which the rest of the product families does. People involved with TED's product family claims this to be due to the fact that TED's product family consists of very complex products, which requires the people working with their development and component problems to have expertise.

The product TED is a running project within the organisation and is managed by the project leader who also has the contact with the customer. The project leader buys the service of producing the product from the production manager who, together with the quality manager and the industrialisation manager, makes sure that the product can be produced. The project leader also has contact with a project quality manager who is responsible for the quality of TED only. In the project there is also a design responsible, who is in direct contact with the project leader and the system owner of TED. The design responsible delegates the work to mechanical engineering designers who make the actual changes, while the system owner is responsible for all components in TED and their capability with each other. For an organisational structure in the project regarding TED, see Figure 4.5 below.

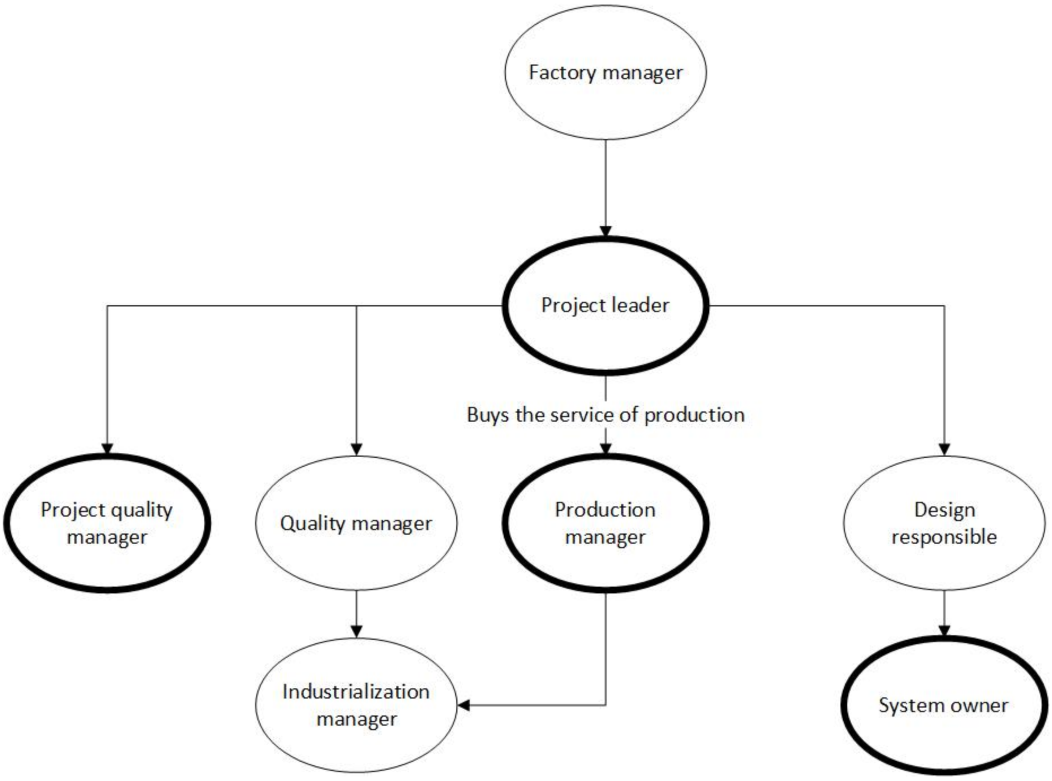

Figure 4.5: Organisational structure regarding the project producing TED, where the thicker circles are the ones being authorized to take decisions regarding TED and its production.

4.2 INTERVIEWS

In this section the result from the interviews is presented. The interviewees are members from the different problem solving procedures and operators reporting the problems. A summary of the interviews with the members of the problem solving procedures can be found in Table 4.8 down below. Furthermore are the results from interviews with operators presented. See Appendix A for interview guide including the questions asked to the interviewees from GG, Andon and MM. The interviewees will be presented as GGX, AX and MMX, where X corresponds to individual X depending on which order they have been interviewed. GG stands for Guldgruvan, A for Andon and MM for Materialmötet.

Table 4.8: Summary of the current problem solving procedures with data from interviews.

	Guldgruvan	**Andon**	**Materialmötet**
Problem types	Problems and obstacles related to open orders.	Problems related to the design of a released product.	Problems related to production of product TED.
Purpose	Operations management and solving urgent problems.	Finding quick remedial actions.	Solving project specific component problems.
Meeting frequency	Every day for 20 minutes.	Every day for 15 minutes.	Once a week for 1 hour.
Standardised work	Yes, but everyone is not aware of it.	Yes, but people are not aware of all things covered by the standard.	No, but an informal standard has been created.
Members	Managers related to all production on site	Mechanical engineering designers and the ones reporting the problems	All white collars related to product TED
Products	All produced in-house products	All released products in-house	Only product TED
Solution	Both short- and long-term	Both short- and long-term	Both short- and long-term

4.2.1 GULDGRUVAN

10 managers from GG were interviewed, GG1 to GG10.

The purpose with GG is to inform about problems and obstacles with open orders, which are orders that are currently in production, that have the potential to stop production. GG gathers the managers with some connection to the production at DSC. These managers are from materials supply, storage, production, design department, etcetera, but everyone are welcome to join the daily meeting.

GG is held every morning for 20 minutes. It starts with a short status review of the situation in terms of orders and the overall material flow in the factory. The problems are discussed and precautions for future work is being decided. Monday to Thursday, problems that are to be solved with short-term solutions are discussed. These problems are often related to different production units in-house and must be solved immediately. On Fridays long-term solutions are discussed for the problems that are in need of long-term-solutions. GG is a fast redundant procedure that has a goal of solving a short-term problem within a 24 hour span but, according to all interviewees, some problems take weeks to solve. All interviewees agree on the fact that there always is 5-20 new problems every week.

> *"The aim with GG is to highlight problems and receive a quick solution."* (GG9)

The different problems are almost always lifted to GG by the managers of the factory which in turn get the information from their team mates in respective group. The manager is writing the problem on the big white board located at the meeting spot. According to GG2 and GG3, the board is divided into two parts, the left part is for short-term solutions and the right part is for long-term solutions which are discussed on Fridays. The board is the only way the managers of the factory can be informed about the rising problems of all production units in-house. Interviewees GG2, GG3 and GG6 state that the ERP system is used to keep track of the different problems while interviewee GG4 and GG5 states that there is no common software that everyone can share. GG2 explains that no common software is used due to the fact that everyone has to attend the actual meeting in order to get the information this way. It is a way of "dragging" everyone to the meeting every day to interact and solve problems.

> "*…I think it is the actual meeting that is the important thing, that we all meet each morning and write our problems on the board, this forces everyone to come to the meeting*… "(GG2)

Except the common whiteboard, the line managers are communicating the problems with each other and their teammates using the ERP system. Here, all NCRs can be found and identified to product and section. According to all interviewees, except GG7 and GG8, the problems on the whiteboard are not prioritised in any way, every problem is as urgent as any other.

When a problem is uplifted to the GG meeting and written on the board, it is time for someone to take responsibility for it. GG3 explains that this usually comes naturally since every manager at the meeting is responsible for a section and if a problem is related to their area, it is an obvious choice to take care of it. After a problem has been delegated to a line manager, the manager will forward it to their area and teams to further work on it. If needed, the different areas of the line managers can communicate to solve a specific problem, but this does not happen often. According to GG7 it is quite common that the person lifting the problem to GG is also the person being responsible for solving it as well. GG7 claims that if one lifts a problem and is in need of help to solve it, that same person should not be assigned the problem.

There is some document about standardised work for GG but most of the members do not know about it or have not seen it. GG2 claims that the documentation about how and what is to be done at GG has been on the walls where the meeting is located, but has not been seen in a while. The majority of the members do not think the way of working is optimal and have improvement suggestions, such as improving the lead time as well as understand why they, not always, can solve a problem within 24 hours. Another suggestion for improvement regarded the standard and how this should be revisited more often.

> *"…I think we should try to help each other faster, like the 24 hour rule we have…"* (GG5)
>
> *"…There should be a better connection between the short- and long-term problems, many times the short-time problems become long-term..."* (GG5)

The authors' perception of the result from the interviews were presented at a workshop where 6 out of the 10 interviewees attended. These 6 interviewees validated that the result were correct. During the workshop the participants did emphasize that the meeting is the most important since then all managers become aware of what is happening on site. In addition to this people from different departments are represented and one can get a holistic view of the production unit. The managers also added that GG is used for operations management and not as a problem solving procedure.

4.2.2 Andon

7 people all related to Andon, either by utilizing it or working in Andon, were interviewed, A1 to A10.

One of the current problem solving procedures at DSC is called Andon. This procedure's purpose is to help with quick remedial actions on problems found anywhere in the chain of released products. Released products are defined as products where all documents connected to a product have been locked and cannot be altered, but new documents can be connected to the product. The procedure Andon consists of two mechanical engineering designers working full-time but during the meetings are also other people, that have reported a problem, attending. The meeting is moderated by a moderator who normally works as a production technician at one of the production units on site. According to interviewee A1, Andon is utilized by many units within the organisation, such as the different projects, purchasing department, manufacturing etcetera and all problems are related to the design of the products. Interviewee A3 agrees that the problems are related to the product design and emphasizes that the mechanical engineering designers are doing their best to solve the problems but since most products are complex, solving these kinds of problems can be difficult. In cases like these, the specific problem is delegated to people within DSC that possesses the expertise within the field.

> *"The design engineers working in Andon does not know everything, but if there is any special competence that is needed, it is their task to send it on. They do not need to solve everything by themselves"* (A3)
>
> *"Most problems that we receive are delegated to other teams that will continue out work, we find the right team that has the design responsibility for the related product and delegate the responsibility to them since they have the solutions"* (A1)

The problems are lifted to Andon in different ways, according to A1 the problems are reported directly to one of the members of the team but also through production technicians, who have directly access to the software used by Andon. According to four other interviewees, the way through the production technicians is common. The software used by Andon is a digital *kanban* board where each problem is put on a card in the software and is continuously updated and moved through the columns on the *kanban* board depending on status. Every problem is owned by a person within DSC which is reporting the problem to Andon. This person will participate in every meeting of Andon until the problem is completely solved and moved to the "done" column.

According to all interviewees, Andon meetings are held once a day and the agenda consists of updating the participants about the progress and status of the different problems, but also to discuss new problems that has been added to the board from the last meeting. The decision for whom is responsible for the different problems are decided on the meetings and according to A1 and A4 the decision is based on who is best suited for that specific problem. According to A7, responsibility is based on how busy people are at the moment and the one who have the least to deal with will usually be responsible for the problem. According to A1, the responsible person will later delegate the problem to the design responsible of the concerned product, who updates the status and progress. A1 and A3 both agree that Andon should be used as a direct problem solving procedure, meaning when a problem is discovered, it should go directly to them for problem solving and therefore only use the production technicians as communicators.

> *"Andon was created as a team containing of engineering designers that would deal with the first phases when a problem was discovered"* (A3)

A1 and A3 adds that Andon should be used as a tool for the production technicians, hence reducing the demand on the production technicians.

The number of problems brought to Andon varies, but about one new problem is discussed at every meeting. According to the software used, the average lead time for solving a problem is 5 days, but interviewee A7´s perception is that it can take all from 10 minutes up to 6 months to solve a problem. Interviewee A6 recently brought a problem to Andon which took six weeks to solve even though it, according to A6, was a relatively simple problem. The problem in this particular case was the waiting time for correction, which has to be done when a change has been made to a design. According to interviewee A1, A3, A5 and A6 corrections on design changes is the biggest bottleneck. The corrections are not done in-house at DSC and the teams working with the corrections are working in 3-weeks sprints, which means that if they receive a correction order in the middle of a sprint, it will be placed in a buffer until the next sprint starts.

Andon works both with short- and long-term solutions to problems according to all interviewees. First, they receive the problem and take action so the related product can proceed in the value chain. Once this is achieved, a long-term solution is about to be created. The long-term solution should eliminate the risk of having the same problems occurring again. The priority of the problems in Andon is based on delivery dates meaning that it is deadlines of delivery that prioritises the problems. This is done with the projects and production planning. The problem solution is then delivered to the one who reported the problem in the first place.

All interviewees, except for interviewee A6 and A7, agreed on the fact that the way of working in Andon is not optimal and can be improved. The improvement suggestions were to improve the correction process since it is the bottleneck and also outsourced; hire more engineering designers that have more special competence since the products handled by Andon are very advanced; and to have more efficient meetings where all different department had their own allocated time.

> *"Improvement could be to add more resources that can battle the correction tasks here, on that point we are limping behind"* (A3)

The information above has been validated through a workshop with 6 out of the 7 interviewees attending. As a preparation for the workshop the authors read through a description of how Andon is supposed to act and what types of problems Andon is dealing with. According to this document, Andon should be used for released products with problems related to the design of the product as well as method and metrological deviations found in the production unit. During the interviews the interviewees only brought up design problems as the focus of Andon, and therefore did the authors asked about method and metrological deviations and how big part of the problems that were related to those categories. The perception of the authors were that the participants were not informed about Andon's focus of also dealing with problems related to method and metrological deviations.

4.2.3 Materialmötet

12 people, all being white collars related to TED and MM, were interviewed, MM1 to MM12.

Another problem solving procedure is the one who is the closest to production of TED since it contains of members like project leader, production technicians, system owner, design responsible, quality manager and production manager of the project TED. The authors had the opportunity to interview all members. This meeting is MM which is held for an hour, once every week. The purpose of the meeting is to be a quick remediation to the production of TED and to highlight problems that can stop production, material handling problems, design related problems and the meeting is utilized for quick decisions. Not all members attend every meeting, but the once in charge of either reporting or solving a problem usually attends.

> *"The aim with MM is to focus on the big material related problems that we have that affects production"* (MM6)

Problems are usually highlighted via the technicians who received the information from the operators doing the assembly and tests of TED. Problems can also be highlighted via the purchasing department or production manager for example. Problems that can create production stoppages or need quick solutions are brought up on the meeting. MM is working with both short- and long-term solutions, but it is mainly used for "firefighting", meaning that the problems lifted are often in a need of a solution right away so the production unit can continue the work.

According to MM1 and MM2, about one or two new problems are lifted to MM every week, and the rest of the interviewees states that there are always about five to ten problems discussed at every meeting. Even though many problems are brought up on MM these are not all existing problems. Many identified problems are often solved outside of MM. This is due to lack of information about what should and should not be brought up on the meeting and the result is that many problems are solved anyway without the MM members' consciousness.

> *"I don't know what should be brought up on MM. I really think there should be a better structure about what should be brought up and not"* (MM10)

The meeting mostly highlights the new problems that has occurred during the last week but also updates everyone on how the already existing problems are in status. Actions are also discussed in how one should work with the problems forward and what actions to take. The meeting is led by the project leader who also is in charge of deciding which problems that are of relevance for MM. The meeting is using an OneNote file to keep track of the different problems. All members do have access to the file and can update it any time.

Six out of the interviewees agree that the different problems are being prioritised after severity. The most severe problems are the ones that can cause production stoppages or production disturbances in any way. These are always prioritised first. Two other interviewees perceive that the project leader is prioritising the different problems, while one interviewee perceive that there is no prioritising at all.

According to the more part of the interviewees the responsibility about the different problems are assigned during the meeting and is based on which member is the best suited. In some cases problems can be distributed to members who are not attending the meeting themselves.

> *"I am usually just assigned a task even when I am not at the meeting. I am not sure how the responsibility of problems is delegated among the members of MM".* (MM10)

After a problem has been delegated, the work continues outside the meetings. According to MM2, MM5 and MM8 the problem is solved individually but it all depends on the nature of the problem, sometimes teamwork is necessary. The time it takes to solve a problem depends on, again, the nature of the problem. There are no regulations on how fast a solution should be provided.

There does not exist any standardised documented way of working according to the members of MM and almost all agree that there is no known work form that they are following or working accordingly. There is a standardised way of proceeding the meetings, which created an informal standard. According to all members, except one, the way of working is not optimal at all. All have improvement suggestions for the meeting, such as improve the structure of the meeting; emphasize that the root-cause has to be found before finding a solution; making the technicians more aware about the product itself.

> *"Most people attending the MM meeting have a production background and have never been working with TED before"* (MM7)
>
> *"Most of the people working on site do not know the product TED and think they are suitable to take decisions"* (MM7)

MM7 emphasizes the lack of root-cause analysis, which he or she considers to be the key for success. MM7 says that root-cause analysis are performed, but not as frequent as it should be, and once it is performed there is no documentation of it. In order to track what has been done to the product it is vital to have good documentation. MM7 is one of the people that has been working with the product since the beginning of it, and due to this he or she knows about almost all previous problems and their solutions, despite the lack of documentation. Due to his or her knowledge, he or she almost always gives a heads up when problem is reoccurring or when a solution to a problem will not be feasible.

> *"Documenting what we are doing is obvious so that we can go back to see what has been done but these things are not performed"* (MM7)

The authors' perception of the result from the interviews were presented at a workshop where 7 out of the 11 interviewees attended. These 7 interviewees validated that the result were correct.

4.2.4 OPERATORS

11 operators were interviewed, OP1 to OP11.

Operators from production were randomly chosen to be interviewed. These interviewees where both assembling and testing operators of TED. The authors decided to interview the operators since the authors wanted a more specific insight of how the operators are working with the product TED, how they deal with different problems, the reporting of the problems as well as their involvement in the problem solving procedures. Due to this, the questions asked to the operators differ from GG, MM and Andon. The questions here were more TED production oriented, see Appendix B for interview guide.

According to interviewee OP3, a faultless TED should take around 2 weeks to build but interviewee OP3 emphasizes that this never happens. The real lead time is instead around 2-3 months according to OP6.

All interviewees agree that when a problem is discovered they are reporting it via the NCR system but also that they are trying to solve the problem after the NCR has been written. If not able to solve the problem, the operators just wait for it to be solved. During this time, the product is idle. OP3 and OP5 explains that there are usually some other things they can work on when discovering a problem that is waiting to be solved. If this is the case, the operators will do other work on TED. Due to this, all operators had a hard time answering how long a production stoppage lasts because, according to them, it almost never happens.

> *"We always have something to do, but if a stoppage occurs the problem has to be severe"* (OP3)

The problem solving time is usually around a few months according to all interviewees but some components to the product TED have been idle for longer periods and some are never solved according to OP9. Different problems with the tests and long-term investigations regarding components of TED tend to lead to the longest stoppages in production. The problem solving is often done by the production technicians, but according to OP5 and OP7 oneself tries to solve the problem if it is possible to do so. Once the production technicians are handling the problem from an NCR, the operators are rarely involved. The exception is when they are feeling that they have a solution to the problem and is trying to help in that way. Some of the operators are not interested in being involved since it is not part of their job to solve problems, while other would like to be updated about the proceeding of the solution.

> *"I would of course like to be involved in the problem solving procedure if this is something that the technicians see necessary"* (OP4)

The perception is also that once the production technicians are coming into production and are asking questions, which will lay ground for the solution, they are not transparent about why they are asking questions. Some of the operators would like more transparency because they might be able to add more information to the subject than the production technician is asking for. The transparency also applies for when a solution is found to a problem, nowadays do the operators perceive that they are not informed about the solutions.

When the authors asked the operators if it usually is the company DSC or the suppliers that are causing problems for production, OP4, OP6, OP8 and OP9 answered that it is the supplier who cause the most production stoppages at the moment. If production in-house is the reason for a stoppage, it usually are the operators unwarily damaging components of TED. These damages can for instance be scratches.

The operators have a morning meeting every other day, meaning 3 times a week, where they go through all TED units and their status. All operators do not attend this meeting since some parts of TED are built separately and due to errors being uncommon on these components, the operators working on these parts usually skip the meeting. According to OP3, one should also discuss quality related problems on this meeting and not only go through the status of the units.

> *"I wish that quality would be included in the meeting where we highlight problems with the units".* (OP3)

The authors' perception of the result from the interviews were presented at a workshop where 7 out of the 11 interviewees attended. These 7 interviewees validated that the result were correct, except the problem solving time which they had thought about after the interviews. They claim that a problem solving time of 2-3 month are very optimistic and rarely happens, it is more often closer to 6-8 months. In addition, the authors asked about on which grounds the root-cause was determined when writing an NCR. The attending operators said the root-cause was randomly decided upon. They were the most certain about the root-cause when there were obvious mistakes from the suppliers, but the rest of the categorisation were decided upon with no logic.

4.3 VALUE STREAM MAPS

Value stream mapping creates a guidance for improvement of procedures. During the interviews it became obvious that GG and Andon are utilized by all products on site, while MM is utilized by only TED. The scope of this project, regarding the improvement of current procedures, is to improve procedures that are only utilized by product TED and not the procedures utilized by other products as well. Due to the scope, only problems solved via MM will be mapped. As stated in Method, section 3.4.1, a VSM should be performed on a problem family, using the problem family matrix, this can be seen in Table 4.9.

Table 4.9: Problem family matrix for problems regarding poor fitting of a component, faulty batch of glue and too stiff cable sleeving, and the tasks the different problems are going through to find a solution.

	Understand NCR	**Bring to MM**	**Initial test**	**Design department**	**Purchasing**	**Inspection**	**Quality check**	**NCR2 reclaim**	**Update document**
Poor fitting	X	X	X	X	X			X	
Faulty glue	X	X	X		X		X		
Cable sleeving	X	X	X		X	X			X

During the study, the authors mapped three problems related to TED. These problems were "poor fitting of component", "new batch of glue does not fulfil the requirements" and "too stiff cable sleeving". The identified tasks were: understand NCR; bring to MM; initial test; design department;

purchasing; inspection; quality check; NCR2 reclaim; and update document. As can be seen in Table 4.9 above the different problems are only going through the same tasks in the beginning. The initial tests are varying depending on the type of problem, but this initial test is to understand if the perceived problem is an actual problem or if it is within specified tolerances. The three approached problems are not considered to be a problem family and therefore one VSM was created for each problem, instead of one single VSM for a problem family.

4.3.1 POOR FITTING OF COMPONENT

One solved problem in MM is the problem of having a component that is poorly fitted to other components, which can cause the component to break during temperature tests. The authors consider this problem's solution as a long-term solution since changes in the design are to be made. The documentation is found in the OneNote file used by MM to manage the different problems, where there are information about when different tasks are about to be due. There are no information about the cycle times or process times available, and when responsible people are asked about it they claim it being hard to estimate a time because it varies. One other thing missing in the OneNote file is how the problem was reported from the beginning and what tasks have been performed before bringing it up to the MM. The authors therefore assumed, based on information from the interviews, that the problem was identified by an operator who wrote an NCR, which is then communicated to a production technician. This production technician should have read through the NCR and understood it before bringing it to MM, where the decision about the official first task is decided upon. For a VSM of this problem see Figure 4.6 below, or Appendix C.

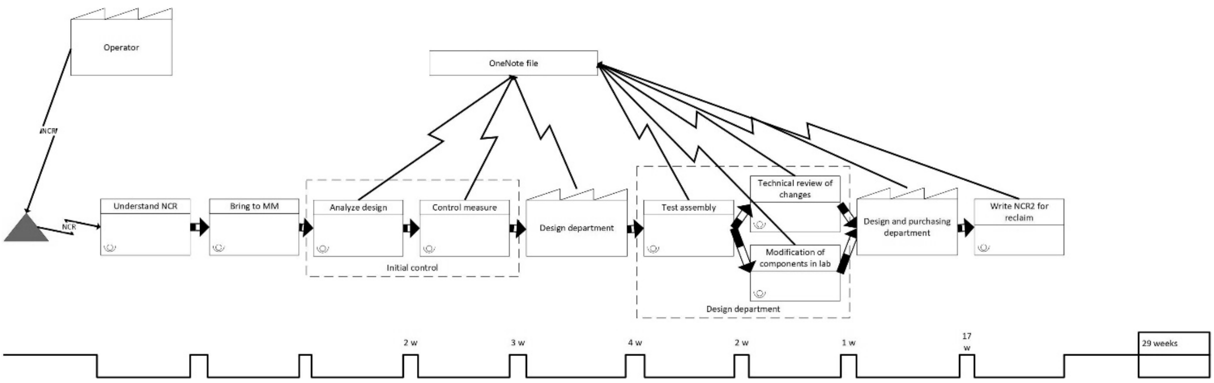

Figure 4.6: Value stream map for a problem regarding poor fitting of a component. See Appendix C for larger scale.

From the interviews it became obvious that the operators were not informed about the progress for the solutions nor what solution it is decided upon. Therefore the authors assumed that the solution is not delivered anywhere.

4.3.2 NEW BATCH OF GLUE DOES NOT FULFIL THE REQUIREMENTS

The documentation for this problem is found in the OneNote file and is rather sparse. For this problem there is no problem description nor found consequences of the problem. The authors assume that, based on involvement in meetings regarding this problem, a new batch of glue is used in production and the operator noticed that the new batch is not like the old one and therefore writes an NCR. The possible consequence of a bad batch is that the glued components are no longer attached due to shearing forces when in use, and therefore cannot fulfil its needs. This is considered as a problem with a need of a short-term solution with a risk of stopping production if the new glue is shown to be faulty. For the VSM for this problem see Figure 4.7 below or Appendix D.

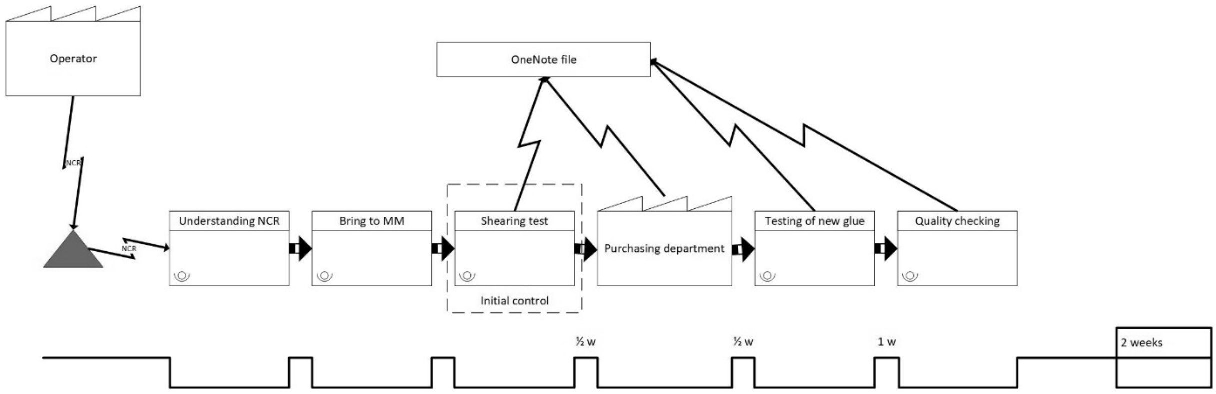

Figure 4.7: Value stream map for faulty batch of glue. See Appendix D for larger scale.

Due to the difference in the batches, the first official step is to make a shearing test of the old and new batch to determine if there is a difference in their effectiveness.

4.3.3 Too stiff cable sleeving

Electrical wires are attached to some components and these wires are protected by cable sleeves. A common problem was that one of the components had too stiff cable sleeves which made it harder to assemble the product and the sleeving was damaged when bent in too harsh angles, which the design of the product requires. The authors assume that the problem is found in production and that an operator wrote an NCR which was communicated to a production technician who brought it up to MM.

In order to proceed the production there has to be modifications to the components in-house, which is seen as a short-term solution. The documentation about the component has to be updated and more specified to prevent the same problem to re-occur, hence seen as a long-term solution. For a VSM of this problem, see Figure 4.8 below or Appendix E.

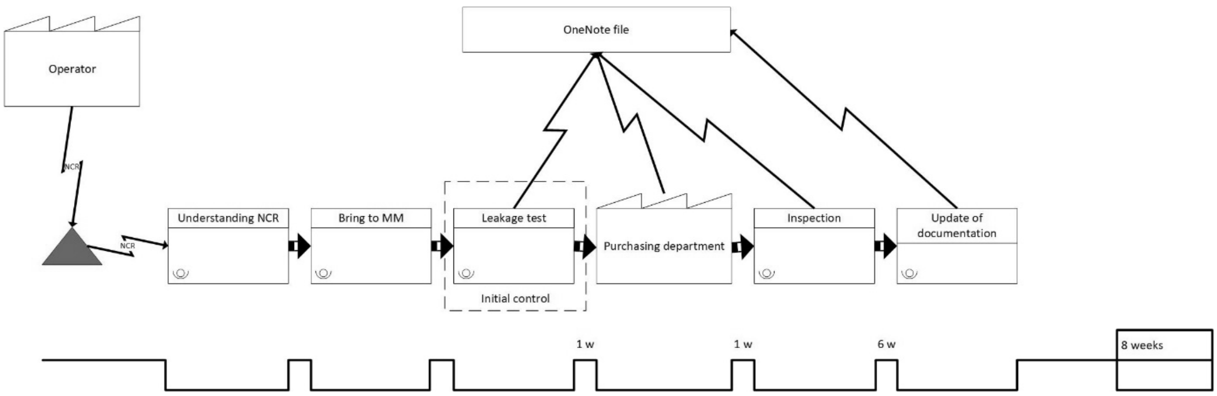

Figure 4.8: Value stream map for the solution of too stiff cable sleeves. See Appendix E for larger scale.

5 ANALYSIS

In this chapter the analysis of the current state is presented. First are the available data regarding NCRs analysed to understand how NCRs are affecting the production system performance and the demand on the production technicians. Further, the current problem solving procedures are analysed in terms of the extent by which Lean practices are applied in current state. Furthermore is the value stream maps of the current state analysed and the Lean wastes are identified in problem solving procedures.

5.1 ANALYSIS OF NCR-DATA

The second research question is "what impact do component problems and their associated problem solving procedure have on the production rate?" and this is answered by analysing the NCR-data from section 4.1.1. The available data do not include information about which problem solving procedure that has been used to solve a specific problem, therefore do the authors only consider the component problems impact on the production rate.

As can be seen in section 4.1.1 there is an instruction about updating the time spent on the specific NCR. These instructions are given to the operators, but the production technicians should also update the time they have spent on the NCR. There is confusion about what time actually should be reported, some operators think they should report the time they have spent so far on the assembly of TED, while others think they should report the time they spend on writing the NCR. Due to this confusion the first reported times are unreliable, this is the reason behind why the technicians do not report the time they have spent on solving the NCR – they feel it is useless to report time further when the already reported time is unreliable. This is further obvious from analysing the interviews where no one, either in GG, Andon or MM, knew how much time they spent on average per NCR. If the time was reported would the interviewees have basis for making a reasonable assumption in the interviews. In addition, the number of NCRs are steadily increasing in the initial buffer, and if the solving time actually was around 1.95 hours per NCR this would not be the case. All these reasons make the authors consider the time spent on each NCR unreliable. The authors consider the problem solving lead time to be several weeks from analysing the VSMs in section 4.3, where the longest lead time is 29 weeks for solving a problem via MM, mostly due to storage in-between different tasks. From section 4.3 the average problem solving lead time is 13 weeks for solving problems via MM, which is far longer than the reported time of 1.95 hours per NCRs. The authors consider one of these problems to be stopping production, which is the problem of new batch of glue not fulfilling the requirements. This because the new batch of glue is detected in production when it is about to be used, which should be when the old batch of glue is empty. Therefore there would not be a possibility for the operators to glue the components correctly, hence causing the production to stop. The lead time for this problem is 2 weeks, which correlates to a production stoppage of 2 weeks. Such a stoppage will limit the production to reach the goal of an increased production rate.

During the interviews did the operators emphasize that the process of writing an NCR s is complicated and takes much time. The authors have had informal discussions with production technicians about the NCR-process. It became obvious that not all boxes need to be filled in before the operators send it to the production technicians. The technicians would like to have information about the problem (step 2, in section 4.1.1), who the responsible person is (step 3, in section 4.1.1) and serial number for the component (step 6, in section 4.1.1). When the operators have taken actions themselves the production technicians would also like to have information about what has been done and what the outcome was. Information about the root-cause, currently determined by the operator, is not required from the production technicians' point of view. As we can see in section 4.1.1, the biggest part of the NCRs are having the root-cause "supplier" and "not established". In the workshop did the operators state that the root-cause they are most certain about is "supplier" but most of the time is the root-cause determined randomly with no reason for the decision. When discussing the different categories it became clear to the authors that there is no definition for the different categories, where the most unclear ones are "not established", "not reported" and "other". The difference between these three categories is unknown even for the production technicians.

5.2 Analysis of Lean practices in the currently used problem solving procedures

The third research question is "how are Lean practices applied to the currently used problem solving procedures?" and this section answers this question. The authors based the analysis on interviews and observatory data. The analysis aimed to find evidence to identify the extent to which the Lean practices *shu-ha-ri*; catch-ball process; *yokoten*; *kaizen*; cross-competence; standardised work; *jidoka*; and *genchi genbutsu* are applied in the current state. Further an identification of if either a pull- or push system is applied within the procedure has been performed. A summary of the outcome of the analysis, in terms of which Lean practices that currently are applied, and which are not, as well as which type of system the procedure utilizes is presented in Table 5.1. The full analysis of the current state with regard to the Lean practices in Table 5.1 is presented in subsections 5.2.1 to 5.2.7.

Table 5.1 Summary of if Lean practices are identified in the currently used problem solving procedures.

	Guldgruvan	**Andon**	**Materialmötet**
Shu-Ha-Ri	No	No	No
Catch-ball	Yes	No	No
Yokoten	Yes	No	Yes
Teamwork	No	No	No
Cross-competence	Yes	No	Yes
Standardised work	Yes	Yes	No
Kaizen	Yes	No	No
Jidoka	No	No	Yes
Genchi genbutsu	Yes	Yes	No
Pull/push-system	No	Push	Push

5.2.1 Application of Shu-Ha-Ri

As described in section 2.1.1, one of the foundations to Lean practices is called s*hu-ha-ri* and is a learning cycle (Liker & Convis, 2011). This Lean practice is especially designed to teach assembly in mass production, hence Toyota´s principle. Thus this does not mean that *shu-ha-ri* cannot be used as a learning cycle in administrative practices as well (Cockburn, 2007). The practice of *shu-ha-ri* is discussed with regard to the problem solving procedures below. Assessment of application of *shu-ha-ri* is based on how the interviewees explained how they are solving a problem and if there is some standard to rely on in the proceeding. From the interviews it became obvious if the persons had been trained or not in solving problems and if no standard exists there is no possibility for *shu-ha-ri* as well.

After careful observations and interviews, the authors realised that neither GG, Andon nor MM utilize a learning cycle such as *shu-ha-ri.* The managers are skilled in their own department responsibilities and have great knowledge and experience of solving the department's problems. However, it seems that the more specific type of knowledge required to solve problems related to TED is lacking, meaning they are not educated in how to solve problems related to TED. The same conclusion can be drawn for both Andon and MM. The authors consider that Andon is not a team but a tool used by all departments and related products in the company. The tool involves of few people in the house that is working in Andon full time who have not been trained for using Andon. When analysing the interviews and observatory data the authors can agree that there is no evidence for using the concept of *shu-ha-ri*.

Regarding MM which started as a temporary meeting that was created when production of TED had many material handling problems which became permanent with time and is not an official meeting. All types of problems related to TED are discussed on the weekly MM. When newly hired production technician have their own first problem to handle, there are no standards nor guidelines to fall back on. The way to approach the problem is truly up to the individual. There are some people to ask for guidance, depending on the type of the problem, but these people are also acting based on intuition rather than facts when approaching and solving a problem. The authors have also concluded that most of the production technicians are consultants, i.e. temporary workers, with contracts reaching from six months to 1 year. Due to this, the authors have understood the importance of a good and effective *shu-ha-ri* cycle. Therefore, the conclusion is that a clearer and more effective learning phase is required.

5.2.2 Application of Catch-ball and Yokoten

Spaho (2012) argue that communication is crucial for a successful organisation, and the authors would argue that this is the case for problem solving procedures as well. From studying the current state, it is clear that communication is ineffective at the DSC. The assessment of application of catch-ball and *yokoten* is based on the findings from the interviews where the communication between the people were discussed.

The Catch-ball process is seen as a communication tool between different hierarchical levels (Liker & Convis, 2011). Even though the catch-ball process is mainly used for high-level goals to be cascaded down in the organisation (Liker & Convis, 2011), the authors consider that this process can be used at smaller departments and less hierarchical levels as well. Therefore the project leader set the project long-term goals, which is communicated to, let say, the production manager who breaks down the goals into an execution plan. The long-term goals will also regard the problem solving hence involving the production technicians. Therefore, the execution plan of how the goals will be achieved is to be done by the production technicians. This plan will be balled up to the project leader with help of the catch-ball process.

A form of catch-ball seems to already be practiced in GG based on information from interviews and observations. According to the interviewees there is a goal to solve a problem within 24 hours, which should be set by the meeting owner. The meeting owner is the head production manager, and the participants are first line managers, hence having a hierarchical difference. Once having a problem, this is first found in the production unit, which is communicated to the managers with less detail, who then brings the problem to GG with even less details. If the problem then is assigned to another manager, whose responsibility is to solve problems like the one brought up, he delegates the problem to his co-workers, hence having a catch-ball process downwards. The authors have not seen this type, or similar, of problem solving in neither Andon nor MM, therefore do the authors consider that Andon and MM are not applying a catch-ball process.

As found in the interviews as well as from observations do both GG and MM have people from different departments attending the meeting, therefore do the authors argue for some kind of y*okoten* within these processes. *Yokoten* is seen as knowledge and solution sharing horizontally and acts as an organisation strategy where the road for success is shorter (Howell, 2014). Organisational culture is key for successfully implementing y*okoten* (Howell, 2014), and since this is already evident in two out of three problem solving procedures do the authors consider it being a part of the current organisational culture. Howell (2014) argues that *yokoten* is not about spreading the improvements that has been successfully implemented, but also to share the "lessons learned". This is evident in MM, where a participant during a meeting said "when we tried to do a similar change several years ago it was a complete failure" and shared the story of why it was a failure.

As mentioned in section 4.2.2, Andon is consisting of a team of two members, and this team is seen as a tool that are used by all departments on site. These two members have the same background and are from the same department, thus not having interactions with other departments more than when trying to understand their problems. This is why the authors consider Andon to not apply the practice of *yokoten*.

5.2.3 Application of Teamwork and Cross-competence

Cross-competence and teamwork have several aspects in common and is therefore here treated under the same heading. This because existing cross-competence is a direct effect of having a good team construction. Having a wide distribution of competence in a team of four to six members will automatically result in cross-competence (Irirna, 2016). There are surely cases where cross-competence does exist even though teamwork does not. This is observed by the authors when people from different departments and experience areas meet to interact. Whether GG, Andon or MM are using teamwork and if cross-competence exists will be analysed below. The assessment is based on both having teamwork outside meeting hours and which competences that are attending the meetings.

Andon contains of mainly two engineering designers interacting daily on the Andon meeting. The other attendants of the Andon meeting can be people from purchasing or other departments for instance. According to the engineering designer's own interviews, any kind of teamwork does not exist between them outside the meetings. They are all working individually but juggle ideas when needed between them on the daily meetings if one get stuck, hence no teamwork. The engineering designers that do have some broad competence to solve problems but the tool Andon does not have any cross-competence since it mainly contains of two engineering designers that have the overall competence which is not enough in many cases. All products utilizing Andon are complex and the interviewees claim this requires special knowledge, hence the competence in Andon is not adequate. While the designers claimed to be competent enough to solve all problems, the data showed that many of the problems idled for long periods of time while the designers searched for people with the right competence to solve the problem. In many cases, the engineering designers do not have the expertise or competence to solve problems and due to this, problems are paused for a long period of time. Therefore does cross-competence not exist in Andon.

For GG and MM, the situation is different regarding cross-competence. Even though neither GG nor MM have any kind of teamwork outside their interactions, cross-competence does still exists. Since it is mainly managers that takes part in GG, each manager has his or her own specialty in their department. The managers are skilled in their departments and about how to solve problems there, not especially in how to solve problems related to TED. Therefore the cross-competence among the managers at GG appears to be high. The managers come to GG with information about any problem, regarding open orders that can stop production in any way, with the hope to get help from other departments that are attending the GG meeting. According to the interviews, the members of GG thinks it is unfortunate that, in many cases, managers are leaving with the same problem in their hands as they brought up, meaning no help from other departments was received.

MM is quite different. Firstly, the meetings are once a week and secondly, it involves other people than just managers for example project leader and technicians. All attendants have their own different responsibilities that are all connected to TED. The members of MM are purchasers, planners, project leader, production technicians, quality project manager, design responsible and system owner. Due to this there is high cross-competence, which is indicated by one of the interviewees as well. All members are from different departments and during the meeting they are communicating about common goals and everyone is informed about the current state of the project. Teamwork outside of this meeting does not exist.

5.2.4 Application of Standardised work and Kaizen

The Japanese word *kaizen* translates "change for the better" which is an improvement made by the ones in the process (Graban & Swartz, 2014). The authors tried to capture the historical development of the different problem solving procedures during the interviews. The assessment of the *kaizen* application is based on if there have been changes or improvements in the procedure and if these have been successful or not.

It became evident that GG especially is working with *kaizen.* Only around 6 months ago they improved the meeting so that the "blame game" was no longer tolerated. The aim was that people would bring up more problems since one did not get blamed for doing something wrongly. The president of GG explained that there is an on-going work on improvement for GG during the workshop. Firstly did the other participants react to this information, which showed the authors that the improvement work was being done without the people in the process. The authors presented improvement suggestions made by the interviewees and the president claimed these are about to be considered in the improvement process. Here it became obvious to the authors that improvements should be done by or with the ones in the process, otherwise it can be a tough time implementing the change due to resistance (Graban & Swartz, 2014).

Andon has been developing over the years, but not in improving the problem solving process, only to add which departments that can utilize Andon as a tool. One major change has been made in Andon, and that is going from a physical note board to a digital note board that everyone can assess all the time. The interviewees claim that the process and the meeting are the same as when Andon started, but the time spent on administrative work, such as updating the board, has decreased. The authors perceive that Andon is not working with *kaizen*, but rather applied a *kaikaku* approach when implementing the digital board. *Kaikaku* is used to describe a big change, which is more of a disruptive implementation than *kaizen* would be (Liker, 2013).

The interviewees of MM told that MM has been exactly the same from the beginning, the only thing changing is the type of problems they are solving and the people involved, thus not having any kind of *kaizen*. The lack of improvements can be due to the lack of standard way of working. A standard is the best way of doing something right now, and if there is no standard there cannot be any improvement either (Emiliani, 2008). Andon has a standard in what problems they are solving, how other people are coming in contact and using the Andon tool and how to proceed when solving a problem. The authors asked questions about the standard during the workshop with Andon, and the participants were questioning about where the authors have found it since they have not seen it. This indicates that the standard is not strictly followed. This seems to be consistent throughout the organisation since GG has a standard, but not all are aware of it or have not seen it and do not know where to find it. GG's standard is a guideline for the meeting; time, place, what order, types of problems and aims. There is no standard in how to solve a problem, but since GG is about operations management rather than a problem solving procedure, it could be considered a standard in the context of GG.

5.2.5 APPLICATION OF JIDOKA

The principle of *jidoka* (quality detection) is basic and can be easily implemented in problem solving procedures like the ones analysed for this project. For this project, *jidoka* relates to whether a problem solving procedure has some kind of task where the quality of the solution is assured or tested. This was identified from the interviews when discussing the procedure of finding a solution. If the solution was found and implemented without testing or technical review, there were no *jidoka.* According to Obara & Wilburn (2012) the best way of achieving a perfect product (in this case a solution to a problem) is to stop the process and fix every small error immediately as they occur. This provides direct built-in quality, meaning nothing is delivered until it is in perfect condition (Obara & Wilburn, 2012).

Since GG is used for operations management and is not a problem solving procedure, quality detection like *jidoka* of products is not performed according to the interviews. After the interviews the authors could also conclude that no form of *jidoka* of products in Andon is performed. This may be due to the fact that Andon is a tool and not a problem solving procedure. The members explained during interviews that Andon is not analysing the process of solving problems and therefore is not performing *jidoka*.

The authors can only conclude that one problem solving procedure is using *jidoka*. When performing the interviews with the members of MM, the authors perceived that MM7 is a key actor for all changes to the product. During the interview with MM7, the interviewee did emphasize his or her long-term involvement with the product and due to his or her interest and knowledge, this member does often inform the other members about the possibility of a solution or not. One example of this are changes to one component of product TED but when discussing this, MM7 can recall from previous experience that these changes has been done before and were not successful as stated above in section 5.2.2. MM7 is therefore providing feedback on the solution of a problem and MM7 is therefore acting as the *jidoka* to the system. Having a person as *jidoka* is not the ideal situation, and *jidoka* would not occur in MM if MM7 was removed from the process since *jidoka* is not built into the process. MM7 has taken this role due to his or her knowledge about TED and awareness of the cost of having to do re-work.

5.2.6 APPLICATION OF GENCHI GENBUTSU

Genchi genbutsu should be seen as a part of the organisation culture rather than a tool (Dos Anjos, 2009). Gao & Low (2013) argues that *genchi genbutsu* is translated to "go and see for yourself the actual situation", while Liker & Hoseus (2008) translates it to only "go and see". The authors will argue for having two different types of *genchi genbutsu*; going to the actual problem to understand it, and attending meetings where the progress of the problem solution is discussed. By going to the actual problem and to the person reporting the problem, the problem description will be clearer and the data is personally verified. Personally verified data is the basis for making decisions – effective decisions are based on facts, not intuition (Gao & Low, 2013). When going to the actual problem it becomes easier to find the root-cause to the problem, which is vital to know before trying to solve the problem (Dos Anjos, 2009). At the meetings decisions regarding the solutions are taken, and Gao & Low (2013) emphasize the importance of making decisions in consensus.

From the interviews is became obvious that GG apply *genchi genbutsu*, especially in the sense of attending the meetings. During one interview and on the workshop it was emphasized that the meeting is important to attend since the discussions that occur are the most valuable. One interviewee said that a physical board is the key to make sure people are attending – one cannot receive information about the on-going problems digitally and therefore needs to attend in order to be up to date. Some interviewees said that a digital board could be beneficial since information then should be available everywhere and not only at the meeting spot, but this would also threaten peoples attendance on the meetings. The second aspect of *genchi genbutsu* – attending the meetings – is considered to be fulfilled for GG by the authors, further will an application of the first definition – going to the actual problem – be discussed. When a problem is about to be approached after a GG meeting, the managers are delegating the problem solving to his or her co-workers who then are going to the actual problem in order to understand it thoroughly. Since the members of GG are managers they are not the ones responsible for solving the problems, but they are delegating and reporting the problem solving progress. Even though the managers themselves are not applying *genchi genbutsu* do the authors consider them applying it, but it is delegated to another person. In conclusion, the application of *genchi genbutsu* is seen to be evident, but delegated to people closer to production and the problems.

When the members of Andon were interviewed, they described the problem solving process as first getting a problem description digitally from a production technician. Once the problem has been described during a meeting the production technician and the one responsible for solving the problem often did go to the problem location in order to see and understand it thoroughly, thus applying the first aspect of *genchi genbutsu* – going to the actual problem. Once the solving process started the production technician was encouraged to attend the meetings until the problem was solved in order to see the progress of it. The problem solver is attending every meeting where he or she reports the progress to the attendants, including the production technician reporting the problem from the beginning. Since the person solving the problem is attending every meeting the authors consider the second definition of *genchi genbutsu* – attending meetings – to be fulfilled by Andon. In conclusion, *genchi genbutsu* is evident to some extent but there is improvement potential. An improvement of *genchi genbutsu* would be to always visit the location of the problem before starting the process of finding a solution.

When solving a problem through the MM procedure there are no guidelines in how to proceed the process. The authors perceive that *genchi genbutsu* in the form of going to the problem, often found at the shop floor, in order to understand the problem as an initial step is uncommon, which became obvious when discussing the procedure with the technicians. This became obvious to the authors from observations and informal discussions with members from MM. Due to this the authors consider MM to not apply the first definition of *genchi genbutsu* – going to the actual problem. The meetings are held once a week and the invitation encourages prioritisation of the meeting but people have a tendency to only attend when they are responsible for a problem. From this do the authors perceive that there is no *genchi genbutsu* in the form of the second definition – attending meetings – neither.

5.2.7 APPLICATION OF PULL/PUSH SYSTEM

Application of either pull- or push systems for administrative processes like GG, Andon and MM in the current state will be analysed below. The type of system is assessed based on the interviews where the flow in the problem solving procedures were discussed.

GG does not operate any kind of production system in administrative processes due to the fact that it is an operations management meeting. Andon and MM, on the other hand, do operate as a kind of production system in administrative processes when solving the problem. As Locher & Keyte (2016) state, applying pull- or push system to nonproduction areas is difficult. The authors have still managed to translate the pull- or push system into the administrative processes of problem solving.

The problem solving procedure itself is a straight up push system because one specific problem is pushed through the problem solving chain, both for Andon and MM, it is therefore not pulled through the chain. But in order for a problem solving procedure to even start, someone has to signal for it. This signal is the NCR written by the operator. This signal or start alarm is an outer pull system. This means that the process from production´s perspective is a pull system because they are the ones starting the problem solving procedure, but the actual process seen from the design engineers and technicians is a pure push system. Therefore, the authors have realised that Andon and MM do apply both pull- and push systems, but in different parts of their processes.

5.2.8 ANALYSIS OF ANDON AT DSC

During the interviews that were conducted with the members of Andon, the members emphasized that they are working exactly according to *andon* theory, meaning they confidently think they are using the *andon* tool the exact way Toyota does. Below the theory of *andon* will be described. However, there are some differences between how *andon* is supposed to be applied according to theory and how it is applied in the Andon problem solving procedure. These differences are described next.

The *andon* tool was firstly used as a lantern that fishermen light at night to signal for help. Basically, it is a way of signalling that the person cannot perform their task and is in need of help. The tool works the same in production whereupon it is used as a signal for help. The worker has the power to stop a process to involve management to intervene and investigate the problem (Walsh, 2016). It is a visual control system that uses an electric light, or other signal systems, to alarm for help when a problem is discovered. This action will stop the line completely and this way quality is built in the product because it will be done right the first time (Monden, 1994; Liker, 2004). No defected products will appear from the existing process if the worker is using the *andon* tool. The concept of *andon* is a part of the *jidoka* practice (Liker, 2004).

When the authors compared DSC´s Andon tool with the *andon* practices in theory, some differences could be noticed. Firstly, the Andon tool takes too long to solve a problem. It is not a fast resolving tool that instantly stops the process to solve a problem. Instead, the tool has a promised problem solving lead time of 6 week which does not align with the *andon* practices in theory. Because of this, most of the members related and working with the product TED do not use Andon as a problem solving procedure, it simply takes too much time. Secondly, the members of the Andon tool do not possess the expertise competence that is required to work as an Andon according to theory. According to theory, the people that rushes to the place where the problem occurred are experts that can solve the problem directly on spot (Liker, 2004). For the Andon tool at DSC, which is used by all departments at the company, the members of Andon seek help from other departments and people since they do not possess the expertise themselves. Another factor that distances the Andon tool at DSC from theoretical *andon* practices is the fact that they resolve design related problems. According to their standardised work document, material- and process related problems should also be resolved through the Andon tool at DSC. During a workshop with the interviewees from the Andon problem solving procedure, which was performed in order to validate the findings, the information about the standardised work document was discusses. To the authors' surprise most members, especially the engineering designers, had no idea that material- and process related problems were a part of the problem solving description of the Andon tool. In conclusion, the Andon tool are in reality only handling design related problems and the standard differs in the sense that the standard also highlights problem solving for other problems as well. By making the members of the Andon tool aware of the standard and widen the cross-competence, other types of problems can be approached as well.

5.3 ANALYSIS OF CURRENT STATE

In this section will the current state be discussed with the value stream maps and the information about the problems presented in section 4.3 used as a basis.

First of all, there is a need of acknowledging the problem family matrix, presented in Table 4.9 in section 4.3. Rother & Shook (1999) and Locher & Keyte (2016) argues to use a problem family matrix when deciding upon a family to perform a VSM on. Since the problems are not a problem family, each problem will be treated with their own VSM. The authors introduced the term "Initial test" as it became obvious that the first thing done in the three chosen problems was to identify if the problem actually was a problem and, if so, the extent of the problem. This step differs depending on what type of problem it is. In the list below the different initial tests are stated:

- Poor fitting of component: analysing the drawings to see what DSC has specified and measure the actual components to see the difference between drawings and reality.
- Faulty batch of glue: shearing test to see if the specified tolerances was met or not since the NCR was written on the basis that the new batch looked different compared to the old batch.
- Too stiff cable sleeving: since the cable sleeving shown breakages when bending it while assembling, a leakage test was performed in order to see if there was a breakage or not.

The level of detail in information differs between the different problems. For the problem with a poor fitting component there are more information about the different tasks compared to the other two where the information is less detailed. The authors tried to gather more information about the processes by asking questions related to the different tasks. The people asked were the ones stated as responsible for the different problems, but also people that are involved when solving similar problems. It is difficult for the people to estimate the cycle times or other data due to the fact that they are working on many things during the same time but also that it differs from time to time. It could also be due to the fact that the information about the task in the OneNote file is consisting of many smaller sub-tasks that it becomes hard to estimate how long all sub-tasks took all together. These problems are similar to the ones Barber & Tietje (2008) identified in the sales process. The information in the OneNote available looks like Table 5.2 down below and therefore have the authors only stated the lead time as the time between the different due dates.

Table 5.2: Example of information about the progress of problem solving in Materialmötet.

TO DO	Responsible	Due date	Comments
Analyse design	Person A	Week X	…
Control measure	Person A	Week X+2	…
Design department	Person A	Week X+5	…
Test assembly	Person B	Week X+9	…
…	…	…	…

The initial tasks of "Understand NCR" and "Bring to MM" are assumptions from the authors based on information from interviews and observations. Members of MM explains that it is waste of time to bring up a problem to the MM meeting if there are no background knowledge about it. Often is "Understanding NCR" reading the NCR and sometimes talk to the person writing the NCR.

It became obvious for the authors from interviews with operators that the operators never were notified when a solution is decided upon to be implemented, hence no delivery of the solutions in the VSM. Sometimes when the technicians perceive that there are reoccurring problems, no matter if they have decided to act upon it or not, the operators are informed to not write more NCRs about the problem. By not informing about changes, and no more NCRs, will the technicians never know if the change was successful or not. The authors consider NCRs to be communication from operators to technicians, and by informing operators to not write NCRs the technicians remove the only feedback loop in the system.

The authors argue that there is no consistent way of solving a problem nor how to document the process of it. Barber & Tietje (2008) claims that the process depends on what type of problem it is and who is responsible, which the authors agree with in regard to the current study.

5.4 Analysis of waste in problem solving procedures

A summary of how the seven applicable wastes were identified in problem solving procedures can be seen in Table 5.3 below.

Table 5.3: The different wastes and how they are identified in problem solving procedures.

Waste	**How identified in problem solving procedure**
Inventory	NCRs in initial inventory
Waiting	Waiting for answers causing the problem to be idle
Defects	Not controlling the functionality of the solution
Underutilized people	Not utilising the operators, no authority to the people closest to the product
Reinvention	Lack of documentation of what has been done causing the same non-successful solution to re-occur
Lack of discipline	People do not know how to proceed in solving problems, people lack knowledge about the product
Limited IT resources	The electronic shared file do not fulfil the needs of the meeting and the proceeding of the solution

One of the largest wastes on DSC is the NCR inventory. The authors have during observations concluded that around 20-40 NCRs are waiting to be handled by the technicians. Having an inventory this big for a production that currently has a production rate of 10 units per month, both new and repairs, is considered too much by the authors. Many of the existing NCRs from a month do usually string along to the next month, since the technicians do not have the time to resolve all of them. During the problem solving procedure, different reasons to why the technicians cannot proceed the problem solving do occur. This can for instance be that the technician is awaiting answers from a supplier that must be fixed. Due to this, the technician is waiting for the next step, hence is the waste of waiting found in the problem solving procedure. Due to communication obstacles at DSC, waiting will occur since communication between the operators and the members of the current MM is not good. When a solution finally has been developed at DSC, it is not always the right one. The solution might not function which creates waste in the process. The technician must now find or develop a whole new solution which takes extra time.

Locher & Keyte (2016) have defined the waste of underutilized people as limited employee authority and responsibility for basic tasks, management and control and inadequate business tools available. The authors have decided to define underutilized people as not taking care of people's creativity, as Liker (2004) have defined it, and not giving people authority and responsibility for basic tasks. It has become clear to the authors that the operators are not involved in the problem solving procedures today. Some operators want to be a part of the problem solving procedure whenever they have some ideas for solutions. The authors consider the current problem solving procedures to lack in taking care of people's creativity due to this. When the authors participated in meetings it became obvious that there were uncertainties in which member should be responsible and who has the authority to actually decide upon changes regarding the product. This was later validated in an interview. During the interview with MM7 it became clear that there were a long chain of people who should approve the change before it became permanent and official, this is something that the organisation manages, hence not in the scope for this project. Responsibilities were decided upon on the meetings, and often people took the responsibility themselves since they felt that it is within their field, but other times this was decided upon by the project leader. The uncertainty of the responsibility and authority was evident in MM.

Waste in the form of poor documentation and lack of knowledge of the people that are supposed to solve the problems does exist at DSC. The lack of communication as the authors have mentioned above creates great waste at the company because the technicians do not know how to proceed in some cases. The lack of communication also exists on the technicians' level, meaning the documentation left after solving a problem is not enough for someone else to understand or follow up on. Also, as mentioned previously, the technicians are mainly temporary workers that do not possess the knowledge about the product TED which creates waste since they many times do not know where to start the problem solving procedure. Due to this, a standard is required to resolve problems in production. The lack of standardised work can be directly linked to another waste according to Lean practices which is lack of discipline. This particular waste points on the facts that standards are not existent, accurate responsibilities on the workers are not existent and that the workers are not following a particular schedule when working. The workers at DSC do in this case actually have their own responsibilities but not in particular areas. Their responsibility is to handle TED but the product is very complex and one temporarily technician cannot know the whole product by himself or herself in such short time, especially when the technician has not been working with the actual product. The lack of schedule goes hand in hand with the above described. The technicians do not follow a particular schedule when working. Often the day is about spending time on solving a problem but when a new problem, which the technician perceives as more important, is reported this will be prioritised and other work will be set aside. Due to this, the technicians must know what is most important, prioritise and work according to some standard when scheduling. The confusion around factors like these creates waste in the process.

Limited IT resources is a waste presented by Bauch (2004) within product development. Product development is a creative process, which the problem solving procedure is as well. Limited IT resources is referring to poor compatibility and capability, and low availability (Bauch, 2004). The authors have seen that the availability of the currently used software, an OneNote file, is not a problem, thus defining the waste as poor compatibility and capability of the software. The OneNote file can be designed as a list that is suitable for its purpose, but in this case the file does not capture every information needed. There is also doubt in what to write and where it should be written. When going through the file, it is not obvious how the file has been utilized.

6 DESIGN OF FUTURE STATE

This part of the report answers the seven future state questions in order to derive a future state consisting of a more effective problem solving procedure. Later, a map for the future state will be presented. This chapter will answer the fourth research question "what problem solving procedure design would increase the production system performance over the procedures used in the current state?" and why the proposed problem solving procedure design is better than the currently used will be discussed in chapter 7.

6.1 ANSWERING THE FUTURE STATE QUESTIONS

Going from the current state to the future state in VSM involves answering seven questions presented by Locher & Keyte (2016). The five introductory questions maps the current state. The latter ones answer questions about the future state proposal, which will be presented further below in this chapter. The questions will be applied on the maps in section 4.3, hence only for MM thus excluding GG and Andon. GG and Andon will further be used as references to understand possibilities and limitations to problem solving procedures and will be used as inspiration for developing the new problem solving procedure. The three different problems were generalised when answering the seven questions.

6.1.1 WHAT DOES THE CUSTOMER REALLY NEED?

The basic principle of VSM is to discern the value in the value stream and then remove or reduce anything that is not value-adding. What is of value is determined by the customer. The customer requirements are answered by the questions: who needs the output; what is required and how often is it required; and when do they need it (Locher & Keyte, 2016). Here, these questions will be answered for the situation at DSC. The customer in this analysis are the people at DSC who needs the solution to the component problems. From the interviews, it became clear that who the customer is varies depending on who is asked and which problem solving procedure it considers. Some answered that the project itself is the customer, others answered that the end-customer is the customer, although the majority considered the production unit to be the customer. Given the perspectives of the interviewees about who the customer is, and with the observations made by the authors while studying the various processes at the DSC, the customer for the problem solving procedures is in the rest of this report considered to be the production unit. The production unit is represented by the operator working in the assembly process, which is the person who also reports the problem in the first place and hence initiates the problem solving procedure.

How often the operator needs a solution is shown in Table 4.1. The number of NCRs per month, in the production unit that TED is part of, is about 60 which corresponds to the number of solutions that has to be generated by the problem solving procedures for this production unit. This number of NCRs is for the production unit that TED is a part of, thus are not all NCRs related to TED, but TED is the most produced product and therefore do the authors consider this data to be reliable enough to base the analysis on. This number of NCRs includes both short- and long-term solutions and includes repetitive NCRs, i.e. every time a problem is found an NCR is written and if the same problem is found on several components, each faulty component is having its own NCR. The takt time can be estimated from having around 21 working days and 60 problems per month which means that about 2.85 problems should be resolved each day. At DSC there are 4 production technicians available 8 hours per day for solving problems related to TED, hence having 32 hours available per day in total. From this we can calculate the takt time using the equation in section 2.2.1. From the calculation below do the authors understand that a problem should be solved every 11th hour.

$$Takt\ time = \frac{32\ hours\ per\ day}{2.85\ problems\ per\ day} = 11.23\ h$$

For short-term solutions, when the operator needs the solution is dependent on when the problem is found and how the inventory levels are. If the component is found to be faulty at arrival control and there are a few more of the same component on stock already the lead time for solution can be longer. Since one of the stocked components is delivered in place of the faulty component the problem can be solved under less time-pressure. While if the component is found to be faulty in the final testing and there are no more on stock the lead time for a solution should be as close to zero as possible. A long-term solution should be found after a short-term solution has been implemented, this to ensure that the same problem is not reoccurring. A long-term solution should be implemented before next batch is about to be produced at the suppliers or, if the problem is found in-house, as soon as possible.

6.1.2 WHICH STEPS CREATE VALUE AND WHICH GENERATE WASTE?

The required steps in problem solving procedure varies depending on the nature of the problem, but on a general level all problems are solved using the same basic procedure. The steps of the basic procedure are discussed in the following.

6.1.2.1 Initial Testing

When a problem is brought up at the MM meeting, the first step involves classifying the problem. The initial tests are being performed to determine if there is a problem and, if so, the scope of it. This classification activity can be seen as value-adding, since knowledge of how the problem affects the production system is generated. The authors determine this step to add value since it determines the consequences of the problem and clarifies it, which is in line with A3 reports and Problem solving *kata* used at Toyota. Initial tests are often involving many departments, hence choosing which initial test should be performed is decided upon on the meetings where one can have inputs from different competencies.

6.1.2.2 Purchasing department

As we can see in the problem family matrix all problems pass through the purchasing department. The purchasing department is the point of contact with the suppliers, and once changes to drawings or requirements are made it must be communicated to the supplier, as well as when the component should be reclaimed. The authors consider this step to add value since the suppliers are the ones realising the actual changes to the components.

6.1.2.3 Guidelines

From the interviews and observations it is clear that there are no guidelines in what problems should be lifted to MM, or how problems should be solved. Due to the lack of guidelines in MM there is no control neither. The authors think that this is a big area for improvement since the lack of controls indicate no quality guarantee.

As previously stated are all people related to TED involved in MM, especially during meetings. At the meetings all competence needed to perform problem solving tasks are present, hence the delegation of responsibility for the next task can be done effectively. The authors perceive that the main problem is the order of the tasks and almost only one task is decided upon each week. An example of this is for the problem with poor fitting component. The initial test consists of two sub-tasks, where it is two weeks between each sub-task. These two sub-tasks could be performed simultaneously during one week only and therefore it prolongs the lead time. In addition are the meetings so rarely so the progress is updated too seldom and less aggressive than it could be.

6.1.2.4 Modification of components

As can be seen in Figure 4.6 there is a task for modifying components so they fit properly together. This task adds rework to components hence prolongs the production lead time for the whole unit. This task is considered to be a task that only generates waste. But this step is only performed on the components until a new batch of components is delivered, and therefore are even the faulty components taken care of so they can be used instead of scrapped. This step could be used as a testing step where the purpose is to understand if the proposed changes actually are feasible.

6.1.3 HOW CAN WORK FLOW WITH FEWER INTERRUPTIONS?

Work in the sense of this project is problem solving. Problem solving work can always be interrupted and usually is. Deciding what is important enough to interrupt problem solving work is important for DSC since today, many things that maybe are not as important as the problem solving itself can interrupt the work. The authors have observed the technicians solving the problems be interrupted by other problems. The issue here is that the technicians have a hard time deciding which problem is the more severe one. Due to these observations, priorities and rankings could be of importance for DSC to minimize interruptions. These priorities and rankings can be made during the meeting were all members are present and the decision is made in consensus.

Another way of making work flow smoothly is to improve the communication between the different workers and their departments. The authors have observed interruptions in the problem solving work due to poor communication. One example of this is the need of communication between the technicians and concerned departments. The authors have observed technicians putting aside problems due to poor communication resulting in no possibility for the technicians to proceed with the problem solving work. The poor communication is evident in delayed answers over e-mails or members not prioritising the meeting for instance. The technicians are then waiting for answers or support which causes delays and interruptions in the process. Many times the technicians do not know whom to ask questions because information about who is responsible for the problem does not exist, a direct result of poor cross-communication.

Usually the production technicians start working on a problem before even going to the point where the problem actually is located. This means that the people working with the problem solving are a bit too eager to start working on the problem, sometimes even before they are all clear about what the actual problem is. This causes disturbances to the problem solving procedure because it can cause the technicians to choose a problem solving procedure that might not be the most optimal one. Optimal in this project is the procedure which takes the shortest time to solve a problem, i.e. the minimum problem solving lead time. Going to the shop floor and see the problem will of course take some extra time in the beginning of the problem solving process work but it can be of great help later on in the process and the time that the technician scarified in the beginning will pay off. It all comes down to creating a smooth flow that is not as interrupted as before and better controlled. A smooth flow is also reducing the WIP which means that the problem solvers should try to concentrate on one or two problems at the time. This is also tied to the prioritising question mentioned above. Getting rid of all interruptions will be difficult, but minimizing them and controlling them is key to DSC.

6.1.4 HOW WILL INTERRUPTIONS IN THE FLOW BE CONTROLLED?

As mentioned in the answer above section 6.1.3, the work flow can be interrupted and usually is, but if the problems could be prioritised effectively, the interruptions could potentially be reduced or eliminated.

The authors have conducted a few ways to control the interruptions according to observations and interviews. One of these is to create a ranking/prioritising system. The ranking can for instance be based on delivery and deadlines, i.e. a TED unit that is leaving with next delivery batch must be prioritised first. Another prioritising way would be to solve the problems that are causing most production stoppages. According to the interviews with the operators, real production stop for TED never occurs since there are always some work to do at each unit even though it cannot be finished due to other complications. This will be one way of controlling the interruptions.

Another way of controlling the interruptions would be to improve the communication between the technicians and the affected departments. These interruptions can be viewed as a poor application of cross-communication. Information flow across departments is inert and simple requests can take weeks to receive. One example of this can be when department A would like to communicate an issue with department B. First there will be a bottom-up communication to the manager of department A. This manager communicates with the manager of department B and then by top-down communication communicates the issue to the people in department B, see Figure 6.1.

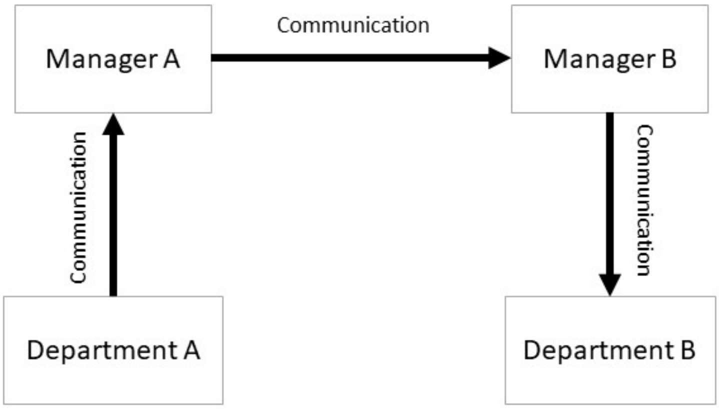

Figure 6.1: Visualisation of the current communication between departments.

One factor that is being affected by poor communication is each person's responsibility area. Many times the technicians does not know what person to contact regarding a problem. Situations like these should be avoided by better communication that is controlled. Due to poor communication, mainly cross-communication, documentation of what has been done and what should be done in the problem solving procedure is lacking. The people in the problem solving procedure are sloppy when documenting what has been done and what should be done in the future, i.e. detailed information about the process is not documented. In general, there is little documentation available about the problems handled in the MM meeting. According to interviews and observations, the authors found that this matter affects everyone working with TED and that documentation must improve because it does interrupt the problem solving work daily. The technicians do not find relevant information in the system which forces them to get in touch with other departments for information and help. Since the cross-communication is poor, this interruption in time grows bigger. If DSC could control and improve documentation at the company regarding TED better, technicians would access information quicker and the interruptions would decrease.

6.1.5 HOW WILL THE WORKLOAD AND/OR ACTIVITIES BE BALANCED?

The interviews and observations has stated that the number of problems, thus the need for solutions, are independent of any other aspect. Naturally, how often a problem will occur cannot be affected and therefore do the authors consider the question of balancing the workload to not be applicable for this specific process.

6.1.6 HOW WILL WE MANAGE THE NEW PROCESS?

Managing a new process is never easy and is often met with resistance, at least in the beginning (Boonstra, 2013). The proposed future state is presented in section 6.2.

Question one to five, section 6.1.1-6.1.5, explains the current state. Answering the sixth question will lead to suggestions on how the future state can be reached. The future state can be seen as a new problem solving procedure. Controlling the different NCRs that the operators write and relate them to the solutions solved using the new process will be one way of managing the new process. By measuring the number of incoming NCRs there will be an indication of how well the long-term solutions are performing. If a long-term solution is feasible, i.e. performing well, the NCRs for that particular problem should be eliminated, and vice versa.

One countermeasure will be the lead time for solving the different problems. Today there are no reliable documentation for how long it takes to solve a problem, but once the time reporting tool is utilised more effective, this documentation will become more reliable. The authors are convinced that the solving time will be quite long (more than 11 hours based on the calculated takt time) in the beginning, but when the technicians are becoming more and more familiar with the new standard, this time will steadily decrease.

Another countermeasure will cover how many NCRs reported during a specific time period that also were solved within the same time period. Some NCRs are long-term thus dragging along for a longer period of time, but most part of the NCRs should be solved within the same time period. From this the efficiency of the problem solving procedure can be calculated as:

$$Efficiency = \frac{Solved\ NCRs\ per\ time\ period}{Incoming\ NCRs\ per\ time\ period}$$

These countermeasures should be measured by the members of the value stream (Locher & Keyte, 2016) which are the technicians which uses the new procedure for problem solving of product TED. This part is done to check if the performance of the new procedure and value stream has improved.

6.1.7 WHAT PROCESS IMPROVEMENTS WILL BE NECESSARY TO ACHIEVE THE FUTURE STATE?

The authors can certainly say after studying the company DSC for four months that the company is in need of a process improvement regarding the problem solving procedure of product TED. The proposed improvement proposals will be presented below. These improvements will lay as foundation for the future state map.

6.1.7.1 Two different procedures: short- and long-term

After careful observations at DSC, the authors can conclude the current problem solving process MM is not good enough due to long lead times in the problem solving process. Due to this, the authors have realised that the new problem solving procure is in need of two procedures, a short- and long-term procedure, which will both act as procedures for solving problems. The authors concluded this due to the variation around the different problems. Today, all problems which are lifted in MM are all different and some require immediate actions while others can wait. Due to the lack of prioritisation confusion about what problem should be solved when occurs. The idea here is that the short-term procedure will handle problems that are acute and require immediate actions, while the long-term procedure will handle problems that are in need of a long-term solution. From observations the authors have realised that many of the problems uplifted in the short-term procedure should later be moved to the long-term procedure since these problems are in need of long-term solution as well.

6.1.7.2 Genchi genbutsu

There is a lack of applying *genchi genbutsu* at DSC. As mentioned in the analysis chapter, section 5.2.6, *genchi genbutsu* can be performed at two stages, either right on site where the problem occurred or more in administrative processes like attending meetings. The *genchi genbutsu* where the technician visits the shop floor is almost not performed at all. The people working with problem solving, usually the technicians for TED, can maybe be too eager to start the problem solving procedure before actually understanding the problem one hundred percent. The other stage where the technicians should attend the meetings to receive information about the stage of the problem, and also report, is applied to a greater extent than the first stage at DSC according to the authors' observations. The technicians for TED attend the MM meeting, but only when needed which proves that *genchi genbutsu* is not performed fully. Visiting the shop floor or attending meetings should not be optional if *genchi genbutsu* is fully applied.

6.1.7.3 Standardised work

In addition to this, a standardised way of working which is mentioned in the theory chapter above is required. The authors have concluded that there is no standardised way of working in MM and no description about how to approach a problem. One of the foundations to Lean practices is standardised work. Today, a standard does not exist for MM and should be implemented. The standard should include information about what steps that should be performed, how meetings are held and who should attend, how information should be handled and what should be documented. The Lean practice principle of *shu-ha-ri* goes hand-in-hand with the principle if standardised work for DSC. Having a standard will provide a learning cycle like *shu-ha-ri* for both new and old members of MM. Learning how to approach a problem and how it should be proceeded, depending on what type of problem it is, is a staple and can be executed through standardised work among others. Since no standards exists at all for solving problems related to TED, such as root-cause analysis and problem solving tools, standards should be implemented, both for the short- and long-term procedure. These standards can also, in the future, act as a basis for *kaizen* by identifying problems in the actual standardised process that are in need of improvements.

6.1.7.4 Communication

Communication is another Lean practice that the authors have concluded, through interviews and observations, is lacking for the current MM problem solving procedure. *Yokoten* between, first of all, the members of MM and *yokoten* between departments is missing. The members of MM emphasize that *yokoten* is lacking between the members today and the authors concluded this is a direct effect of the members not working in teams. Teamwork is one of the foundations to Lean practices and one benefit from working in teams is the more effective communication. The distance between the people are shorter and Spaho (2012) argues this lays ground for faster and more punctual communication. Due to this, the authors realised that since the members of MM do not work in teams, the communication between them are automatically inferior and slower than if they would have worked in teams. One thing to have in mind here is that not all problems are suitable to solve in teams and therefore the authors do not claim that the members should work in groups, only that teamwork can improve the problem solving for some problems and that communication will travel quicker than it does today.

The tool used today for communication is a shared electronic document accessible to all members. This file documents the different problems and their status. As was explained by the members of MM, the tool is a poor form of communication for various reasons. The file is not specific enough to document problems, meaning the file is not made for communication between the members. It functions as a documentation file where the president of the meeting can write shorter notes on what has been done from week to week. There are no directions of what should be written and how the tool should be used. Outside the meetings, people are not rigorously updating the file with everything that is going on, only the main points such as “the supplier says it is ok” or “the tests shown good results” are documented. According to the members of MM a more specific system, like the *kanban* board used by Andon for instance, would be better suited. In such system can the members write comments and connect the problems digitally to each other so that the members can keep track of what problems are on their responsibility. A system like a digital *kanban* board is also visually better since it has columns for the status of the problems. The different columns are different tasks and once a problem is finished in one task it is moved to another column. Using the right tools for communication between the workers when working with problem solving is an important aspect to consider. Tools can vary depending on what kind of procedure that is using them, but overall the communication at DSC for problem solving regarding product TED should be improved.

6.1.7.5 Non-conformance reports

Regarding the NCR system mentioned in section 4.1.1, the operators emphasized confusion about what should be reported in the NCR system and what should not. Some of the operators claim that every error should be reported in the system, regardless of if the same error has been fed into the system several times before without progeny or not. Other operators claim that they have been feeding the system with the same errors over and over again and that they have stopped because the problem does not get fixed by the technicians, for different reasons. This confusion about what should and what should not be reported into the NCR system require guidelines which is missing today. The guidelines should include information explaining that all problems and deviations should be reported with separate NCRs. Additionally, the operators also emphasise the absence of feedback information from the technicians when a problem is handled in a problem solving procedure. The operators explain that the absence of feedback on status of how the problem solving is proceeding, is one of the factors that contribute to confusion. Due to this, the operator should have access to the documentation regarding the progress of the solutions. By having access to the documentation, the operator can follow the progress of the solution and therefore receive direct feedback.

When the authors asked questions about the actual NCR reporting system to the operators, the answers where coherent. The overall view is that the NCR system is too complicated. Training for the NCR system has been provided and there are instructions available for how to write an NCR, but yet do the operators perceive that writing NCRs is too time consuming and requires deeper knowledge. Some of the operators are avoiding reporting errors due to the complications. Other operators explain that they are doing their best to fill the NCR report but that they know they are doing it wrong. After discussions with the technicians about what information they actually need from the NCR, it became obvious that the reporting could be a lot easier. From an easier reporting system, it will become less demanding to write an NCR and therefore should the operators report everything being faulty, including the things not being reported currently. This would mean that the number of NCRs will increase, but the technicians will become aware of all existing problems. By having easier NCR reporting, with a standard describing the reporting process thoroughly, a learning cycle can be applied for the operators learning the new reporting process.

6.2 MAP OF FUTURE STATE

It became obvious from interviews that the purpose of MM was to take care of both short- and long-term solutions, but in reality nobody actually spent time on the long-term solutions, so often a temporary solution became a permanent solution. To make sure that the short-term solutions was taken care of to find a long-term solution did the authors present two different procedures that are intertwining. Short-term solutions are discussed at a meeting called the short-term (ST) meeting in the ST procedure, while the long-term solutions are discussed at the long-term (LT) meeting in the LT procedure. A picture of the map can be seen in Figure 6.2 and Appendix F.

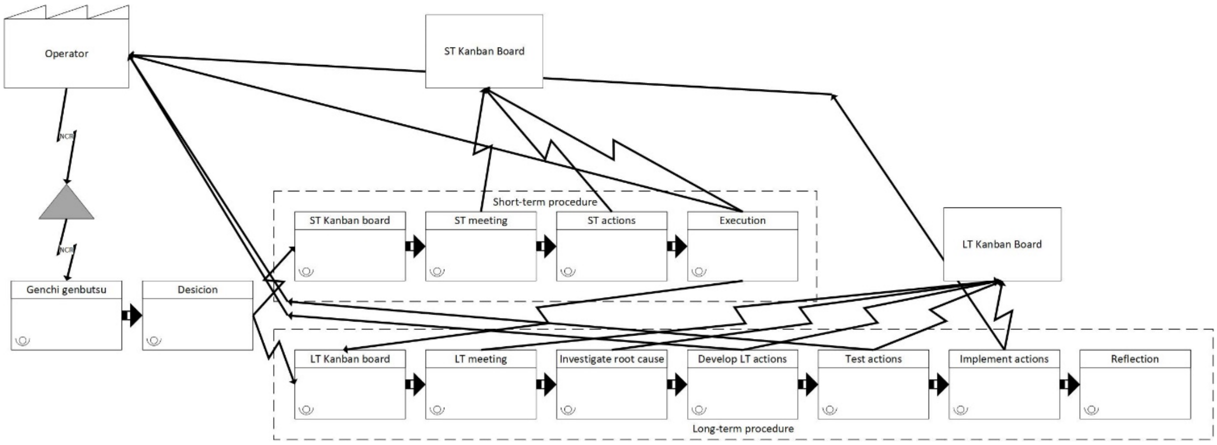

Figure 6.2: Map of future state for the problem solving procedure regarding product TED at DSC. See Appendix F for larger scale.

The future problem solving procedure for long-term solutions is based on MM since it is the only currently used problem solving procedure not affected by other products than TED. Andon and GG, even though they have not been further analysed, will still exist and be available for the production technicians to use. The authors' recommendation is to not use Andon since the problem solving time is perceived to be too long. GG, on the other hand, is recommended to use, but not as a problem solving procedure. GG is a tool for operations management, therefore the people being responsible for a production unit are the ones who should inform about problems at GG meeting, in this case it is the industrialisation manager or production manager. The problems discussed at GG are the ones related to open orders that can cause the order to be delivered late.

Before the production technicians can even act upon a problem an NCR will be written by the operator. The only information the production need the production technicians need to start acting on an NCR is a short description of the problem, who the responsible person is and the serial number of the component. By excluding the other steps will the NCR reporting process become easier for the operator and misunderstandings and over-processing are avoided. This also leaves room for the production technicians to use the time reporting tool in the software and report the correct time spent on each NCR. The reporting is not only regarding the time, but the *kanban* cards will also be updated for each task that has been done to find a solution. In the software used for the *kanban* board people can comment in every card about the progress, decisions and attach mail conversations regarding the solution development. A guideline to use when thinking about reporting is that any person should be able to read through the comments and understand the whole progress.

As answered for the question regarding management of the new problem solving procedure, section 6.1.6, the moderators will measure the efficiency of the problem solving procedure using the equation in section 6.1.6. As seen in the equation the maximum value of efficiency will be 1, i.e. all incoming NCRs per a time period are solved during the same time period. The time period will differ depending on the procedure, when measure the ST procedure the time period should be shorter than the LT procedure. Once implemented the current efficiency can be calculated and a goal of the efficiency can be decided upon. For example, the efficiency in the ST procedure is calculated to be 0.5 in the beginning, then the goal can be to increase with 30%, i.e. the efficiency goal is 0.65. Once this goal is reached a new goal will be set. When the countermeasure have been implemented and understood properly, measures of "good" and "bad" can be implemented. For example, "good" efficiency is when being 10% from reaching the goal while "bad" efficiency would be when being 30% from reaching the goal. If the goal is 0.8, "good" efficiency would be 0.72 and "bad" efficiency would be 0.56. Measurement of the efficiency should be updated before every meeting and be reported to the other members during the meeting.

These different tasks, described in Figure 6.2, and their order will act as a standard in how to resolve component problems. Further are the different tasks described under each subheading. This map is translated into a standard presented to DSC. This standard can be found in Appendix G.

6.2.1 GENCHI GENBUTSU

Before anyone starts working on any solution, short- or long-term, understanding the problem is very important. Because of this, the authors have implemented *genchi genbutsu* before any problem solving solution is discussed. *Genchi genbutsu* will be performed here as going in to production, or wherever the problem occurred, and truly understanding it by asking the questions related to the problem. These questions are asking "when", "how", "what", "why" and explores if the reporting operator has an idea for solution or if the operator would like to be involved in the problem solving procedure. These questions can be seen in the standard in Appendix G. *Genchi genbutsu* will be performed right after receiving an NCR from the operators. It is the technicians who receive the NCRs from the operators. Figure 6.2 shows a buffer of NCRs which is unavoidable since the technicians are not available to start working on an NCR immediately after it is written. Therefore, an NCR buffer is placed before the *genchi genbutsu* stage.

6.2.2 DECISION

At the decision stage, the technicians are supposed to decide whether the problem should be solved short-term with immediate measures needed, or long-term. If the technician decide that the problem is in need of an immediate short-term solution, the problem should be uplifted to the ST procedure, further explained in section 6.2.3. If the technician decide that the problem is in need of a long-term solution only, due to the fact that the problem is not a risk for stopping the production in the near future, the problem should be uplifted in the LT procedure, further explained in section 6.2.4.

6.2.3 SHORT-TERM PROCEDURE

The ST procedure is for problems that have the ability to stop production, this will therefore act as the theoretical Andon with some adaptions. This procedure is visualised in the top part of Figure 6.2. In the ST procedure there will be a stand up meeting held every morning for maximum 20 minutes, called ST meeting. The attendants of the ST meeting will mainly be the technicians but depending on the nature of the problem, the members of the ST procedure can send out an invitation to people within the project that can be of help when solving a specific problem. The idea here is that problems that have been solved using the ST procedure will later be moved to the LT procedure for further development of a long-term solution.

6.2.3.1 ST kanban board

The first step the technicians should perform is to create a new digital *kanban* card and place it in the backlog of the *kanban* board in the software used. The card should contain of important information about what the problem really is about, i.e. the information gathered in the task *genchi genbutsu* in section 6.2.1. The card should consist of dates on when the problem occurred and should be updated every day on how far in the problem solving process the problem is. The moderator of the ST meeting will be able to move the cards on the actual meeting or later on to the different columns. The existing columns will be "ST Kanban board" which acts like the backlog, "ST actions" and "Execution". The *kanban* board can be seen in Figure 6.3.

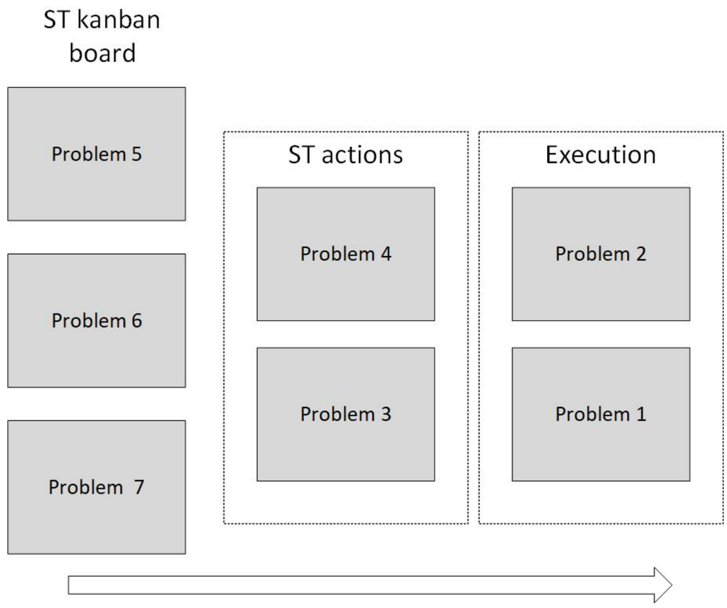

Figure 6.3: Visualisation of how the kanban board for the short-term procedure can look like.

6.2.3.2 ST meeting

The next step for the technician would be to prepare the problem and bring it to the daily ST meeting. The technician should be able to describe and present the problem in detail so that the rest of the members can understand it. The idea here is to seek either information or help from the other members, but also to update the other members on the status of the problem if no help is needed from them. Either the technician receives help and/or information from the daily ST meeting, or the technicians attend the meeting to update the rest of the members about the status of the problem.

6.2.3.3 ST actions

The next step will be to act. Short-term actions on how to solve the problem must be planned and taken here. Any action necessary to solve the problem short-term will be planned and taken. This action will only be temporary. This means that a long-term solution still has to be developed later on but the short-term solution will be used as an interim solution. The short-term solution will help production to move forward so that production does not stop. It will be the technicians who develop and execute the short-term solution. They will also have the responsible to give feedback to the operators on the process and how the solution will ease the production error.

6.2.3.4 Execution

The execution step is where the short-term solution is implemented. Here, it is important for the technician have a dialogue with the operators working in production so that the operators will be updated about what solutions is implemented and what changes will be made in production. After the solution has been executed, the *kanban* card will be moved to the backlog on the *kanban* board for the long-term procedure.

6.2.4 LONG-TERM PROCEDURE

An NCR, or a communicated concern, from an operator is not always a problem stopping production, but is more of the nature that there is a possibility to stop the production, hence a need of a long-term solution. Long-term solutions should also be developed when a short-term solution has been executed. The long-term solution is preventing the same problem from reoccurring.

The authors have based the long-term solution procedure on the current procedure MM, hence creating LT procedure, this is visualised in the bottom part of Figure 6.2. The members will be the same as the currently ones: project leader, production technicians, purchasers, material planners, quality manager, mechanical engineering designer and system owner. The procedure will be managed on a meeting called LT meeting. The meeting should be as close to mandatory as possible, but one cannot demand everyone to attend every meeting. Every member should understand the severity of the problems and therefore the importance of the meeting, and from this it should be obvious to attend. The meetings will be held once a week for an hour in a meeting room, far from distractions. The meeting agenda is to first announce new problems so everyone are aware of them, followed by an update of the progress for proceeding problems. Almost all process steps are held independent of the meetings, and therefore do the meetings only acts as information sharing and check points. The different problems will be managed as a *kanban* project, with a digital card wall and digital cards. Movement of the digital cards is also done on the meetings, this ensures that all members are informed about the current state of the problem. The different columns are the different tasks, where the first one is "LT kanban board" which acts as the backlog, followed by "investigate root-cause", "develop LT actions", "test actions", "implement actions" and "done". The *kanban* board can be seen in Figure 6.4.

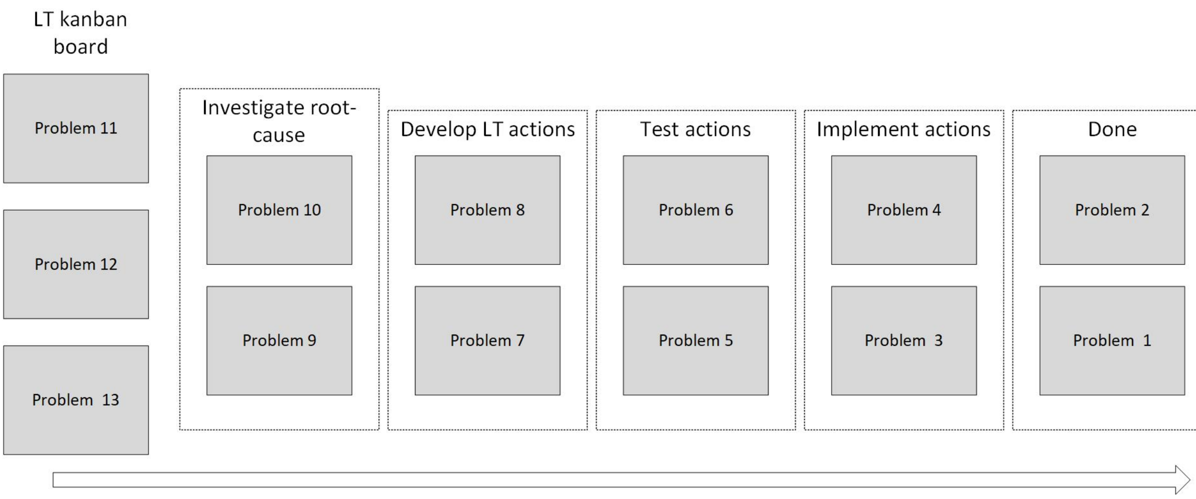

Figure 6.4: Visualisation of how the kanban board for the long-term procedure can look like.

6.2.4.1 LT kanban board

This process is basically to write the problem as a digital card on the digital *kanban* board available for the LT procedure. The information on the card should include information gathered from the process step called *genchi genbutsu* and, if it comes from ST, all information leading up to the short-term solution and what the short-term solution is. Hence, all information about the previous process steps should be available in the *kanban* card for everyone to see. This step is done by the production technician responsible for that specific problem.

6.2.4.2 LT meeting

Here the problem is discussed with all members. The person responsible should inform all about what the problem is about, and all others are informed about the problem and can come with input.

6.2.4.3 Investigate root-cause

This process step can change place with "MM 2.0 meeting" if the person responsible can manage to perform a root-cause investigation by him/herself. When trying to find the root-cause it will be feasible to have people with various backgrounds to not miss out on causes, hence booking a meeting for performing a root-cause analysis in a team. The root-cause can be determined in various ways, but 5-

why investigation is commonly used at DSC today and is the analysis method that the authors will recommend to use for root-cause analysis.

6.2.4.4 Develop LT actions

Once the root-cause is found, long-term actions against it will be taken. Often the person being responsible for the problem is not the one that has the knowledge to take actions for a problem, for example there might be a need for changes in the drawings, and therefore the design responsible will be the one taking actions. When the root-cause has been identified it will be announced on the next meeting. During the meeting it becomes obvious who should be responsible for the development of actions. In this step the operators will be involved since they have input of what can be achievable and even have suggestions of what to do.

6.2.4.5 Test actions

When an action has been developed it is time to test it. The test could be to try out a prototype of a new design of a component or getting the first batch from a new supplier and try them out. Since most trials are made in real life production the operators will be highly involved, and therefore it is vital to inform the operators in this step. The information should include what is about to be tested, how many products will be affected, how this might affect the production and how the operator should inform about success or failure.

6.2.4.6 Implement actions

Once a test has shown success it should be implemented. Here everything that is affected by the change will be altered – instructions updated and decisions about the old version of the component will be taken. The operators will be informed since they will notice a change in components and it can cause confusion if the change is not communicated.

6.2.4.7 Reflection

Now, the implementation is successful and this is communicated at a following meeting where the digital card is moved to the “done” column. When the card is being moved, a discussion about “what did we learn during this problem solving process?” should be encouraged and there will be room for discussions about improvement potential and what actually worked well and what did not.

7 Discussion

In this chapter Lean practices in problem solving procedures and application of value stream mapping for problem solving procedures will be discussed. The discussion will be around the research questions. Further discussion around how production system performance is affected by problem solving procedures and sustainability aspects considered during the project will be performed. Additionally further research recommendations will be presented.

7.1 Lean practices in problem solving procedures

This section discusses the answer of the third research question "How are Lean practices applied to the currently used problem solving procedures?" and how Lean practices are applied to the suggested problem solving procedure.

After investigating the application of Lean practices at DSC, the authors concluded that not many Lean practices are applied today. Because of this, the authors have developed new standard approaches on how to solve component problems, both short- and long-term. How the Lean practices are applied to to the suggested standard is described below.

When improving the problem solving procedure the authors were inspired by different ways of solving problems at Toyota. Liker (2004) argues that everyone at Toyota is seen as problem solvers, including the operators. In the beginning of the project the authors were convinced to adapt this view of problem solvers by including the operators in the problems solving procedures, but interviews made it evident that operators are not always interested in being part of the solution process. Since the operators said that they sometimes have ideas for solutions, the authors thought these ideas should be captured as early as possible in the problem solving procedure. This is solved by *genchi genbutsu* in the beginning, where the production technician actually talks to the reporting operator, who at that point can speak their mind of involvement and ideas.

Generally the authors were inspired by problem solving *kata* presented by Soltero & Boutier (2012) in the development of the new problem solving procedure. The authors identified a clear point in the steps of the *kata* where a short-term solution was developed (see step 2 in section 2.2.4) where the rest of the steps were aiming towards developing a long-term solution of high quality. The different steps were used as inspiration for the new processes, but the description of them were adapted to the problem solving procedure. Soltero & Boutier (2012) argues that *kata* is a learned behaviour which is learnt from repetition. When adapting problem solving *kata* there will steadily be improvements. The improvements will be improvements to the problem solving procedure, its tasks, problem solving lead time and, in the long-term, solutions will be of higher quality and more feasible. The solutions improvements are due to the fact that the problem solver becomes more and more skilled at solving problems. The overall effect of problem solving *kata* is that the performance will increase due to higher quality products and, most importantly, shorter lead times. The shorter lead times are a result of an improved problem solving procedure.

At DSC they have their own A3 report consisting of five steps: problem description; immediate actions; root-cause analysis (5-why investigation); action plan for permanent countermeasures; and follow-up and evaluation. This differs from the A3 report presented by Weber (2010) where there is no section for immediate actions, hence aiming for the long-term solution right away. The production technicians are encouraged by upper management to write at least one of these A3 reports each month, but the production technicians consider this type of report to not be applicable for all types of problems. Additional confusion occurs when the problem solving procedure is moving over different departments, then there is a question of who should write the report. The authors have not included this A3 report in the problem solving procedure, since people are refusing to work with this and the documentation in the cards on the digital *kanban* board is easier than an external document being sent from department to department. Digital *kanban* boards are in use already at DSC, one example is for managing the problems in Andon, as can be seen in section 4.2.2. The knowledge about the *kanban* boards are already existent, even for the production technicians working related to TED who manages other projects as in *kanban* project management. All information about the problem will be available in the *kanban* card, hence being available even after the problem has been solved. The best solution would be for the upper management to not encourage A3 reports, but instead understand people's responsibilities and what has been done through the *kanban* board. The upper management would probably still encourage A3 reports, since these are uploaded in the ERP-system and available to everyone having access to the ERP-system. The writing can be done after a problem has been finished due to the extensive information available in the *kanban* board. The technician being responsible for a problem would then be responsible for writing the A3 report. In the future there might be a built-in tool in the software used for the *kanban* board where there can be categorisation of the different inputs, and based on this categorisation there would be a possibility to generate an A3 report automatically. This A3 report would then be uploaded to the ERP-system. If the more part of the departments at DSC uses the same software to manage all their problems, there might be a possibility to synchronise this software to the ERP-system to avoid rework and wasting time on doing something that, more or less, already has been done, i.e creating and uploading A3 reports. By not redoing work and using the same software, the time spent will decrease which will, in the long-term, add to the improvement of the performance.

7.1.1 SHU-HA-RI IN PROBLEM SOLVING PROCEDURES

The existing MM does not use any kind of learning cycle like *shu-ha-ri.* The technicians who are supposed to solve the problems in production for TED are basically just thrown into the MM meeting and are expected to solve the problems related to TED. The authors have argued previously about the importance of a good and effective *shu-ha-ri* cycle due to effective learning for new employees. Having a good and effective way of teaching new employees the way of working and how the problem solving procedure should be executed, having temporary workers should not be a problem for the company. When a new employee is put into learning through the s*hu-ha-ri* cycle, the learning period will be decently short and the technician will be able to start working independently quick. If an employee involved in MM decides to quit the company, a new one can be brought in and trained quick enough to not interrupt the problem solving procedure. Due to this, the *shu-ha-ri* cycle is very important for DSC which operated with temporary workers, both for the ST and LT procedures.

The Lean practice s*hu-ha-ri* will be implemented in both the long- and short-term procedures. Since the authors have developed a standard, the *shu-ha-ri* cycle will automatically be integrated. Learning the standard requires training from someone else, thus the *shu-ha-ri* cycle. As mentioned in the theory chapter, see section 2.1.1, the *shu-ha-ri* cycle is divided into three phases. The first phase, the *shu* phase, is where the person is supposed to learn the standards by imitating the teacher or leader. The basics are simple, follow the leader and imitate to learn. For the second phase, the *ha* phase, the person learning the standard is still under supervision but is free to work on his or her own. For the third phase, the *ri* phase, the person is free to try for himself or herself and implement new ideas. If he or she discovers new ways of working and realises that these are better than the existing standards that the authors have suggested, he or she is free to change them.

The authors realised that the new suggested standard does open up for implementing s*hu-ha-ri* since the workers need to learn the standard. For the ST and LT procedure, the standard must be learned and then taught to new employees.

7.1.2 CATCH-BALL AND YOKOTEN IN PROBLEM SOLVING PROCEDURES

Liker & Convis (2001) argue that catch-ball is communication over hierarchical levels, often used for cascading down higher-level goals in the organisation. The authors have adapted this into communication between different levels in a project instead of an organisational communication. It became obvious from the interviews that only GG was utilising some kind of catch-ball process while the other two procedures were not. By implementing someone who is in charge and set the goals for the procedures, such as priorities and solution goals, a catch-ball process should be established. By implementing a catch-ball process, the goals will actually be translated to an execution plan. Thus, the goals will be reachable. If the goals are not reachable, these can be adjusted with the catch-ball process. Working towards goals using execution plans and standard procedures, the performance will increase because time will not be spent on confusion about what and how goals will be reached.

The ST meetings are moderated by a moderator, who is a production technician working with solutions, which will communicate e.g. the number of days it should take to solve a problem. There will not be any communication about priorities of problems since the ST procedure will only deal with problems which will cause production stoppages in the near future, thus all problems being equally important. There are no hierarchical levels in the ST procedure and due to this can the authors not consider this type of communication to be of catch-ball process within the ST procedure. Outside of the ST procedure hierarchical levels do exist which provides catch-ball communication. Hierarchical levels is not something that would benefit the ST procedure since the focus here is to keep production running. The moderator of the meeting can still communicate with higher levels of management about what is performed, and if something is needed, for the ST procedure.

For the LT meeting there are the same members as for MM. In MM the project leader is the moderator and the meeting is where he or she gets updated about the different problems regarding TED. This will be kept for the LT meeting. The moderator, i.e. the project leader, has to be in charge of setting the goals for the project and communicate them to the others operating in the project. The goal could be to increase the production rate, which will affect the LT procedure in the sense that the problem solving time will decrease and the solutions has to be robust resulting in the same problems not occurring again. The way to execute and reach the goals will be set by the person responsible who communicates this on the meetings and consensus about the execution plan will be made. Here, it is important for the moderator to not work as a manager in the sense of "bossing" but more like a "coaching friend" who stimulates and coaches the members of the ST and LT meeting. The moderator, together with the members of ST and LT meeting are in charge of making sure the meetings start and ends at the right time.

The participants are important to consider when talking about communication since it is crucial for success (Spaho, 2012). Due to the difference in the people attending the meeting, a horizontal communication between different departments will occur, which is called *yokoten*. It became obvious for the authors from participating in meetings with MM that knowledge sharing already was common, but in the LT meeting this will be further encouraged. The LT procedure is also adding a process for reflection. The reflection process will be performed at the meeting, hence people involved in solving a problem will share successes and "lessons learned" just as Howell (2014) emphasizes the use of *yokoten*. The effects here will be that the communication and knowledge sharing will travel quicker over departments. The reflection process will lead to an improved problem solving procedure as well as self-development for the technicians, resulting in more efficient problem solvers. The communication, knowledge sharing and reflection parts will lead to an improved performance of the problem solving procedure.

In the ST meeting there is a possibility for *yokoten* depending on the participants. The mandatory participants will be the production technicians, with different responsibilities, while other participants will be invited depending on the need for help from other departments. When the production technicians work together with no other help or communication, *yokoten* is not applied. If the production technicians would communicate with other departments though, *yokoten* would be applied.

Yokoten is about knowledge sharing. Liker & Hoseus (2008) translates it as "learn from" while Liker & Convis (2011) translates *yokoten* to "across everywhere", which can be the case for the new problem solving procedure. Currently is this problem solving procedure adapted to TED only, and through *yokoten* people involved in the problem solving procedure can spread the word of working with TED, i.e. benchmark internally in the organisation.

7.1.3 TEAMWORK AND CROSS-COMPETENCE IN PROBLEM SOLVING PROCEDURES

In the analysis, the authors stated that cross-competence exists in MM even though teamwork outside the MM does not exists.

For the ST meeting, cross-competence will still be existent even though the people who possess this cross-competence are attending the meetings every morning. The authors think it is more efficient if the problem solvers, the technicians, are present each morning since they are the ones possessing the knowledge about actually solving problems short-term. If they are in need of other help, communication via e-mail or phone is the easiest way to inform for instance the quality manager to attend the meeting next morning. This means that cross-competence does exist, even though it is not present each morning but is always available when needed. The technicians are the ones responsible regarding the problem solving. The fact that cross-competence is not present each morning is not considered a problem. When the communication improves using *yokoten*, communication with other people or departments will not lead to delays in the problem solving process since this way of communication is quick.

For the LT meeting, not much regarding cross-competence have changed. The members are encouraged to attend every week at the meetings and due to this, cross-competence is present at all times. The authors have decided to not touch much upon cross-competence since MM already has such high level of cross-competence.

As mentioned above in section 4.2.3 and in the analysis in section 5.2.3, the members of the current MM do not work in teams. The authors have realised the importance of teams during their study at DSC and the benefits it would bring to the members of both the ST and LT procedure. This has been realised from observing different problems being solved. The authors have desired to put this responsibility on the moderator for the ST and LT meeting. It is important for all members to understand the importance of working in teams and the benefits of it, especially when finding the root-cause in the LT procedure. For the members who have never been working in teams in MM, a transition could be difficult. Due to this, the moderators will be responsible to emphasise the importance of working in teams outside the meeting hours as well. For the ST procedure, the technicians will be able to work on a short-term solution in teams outside the meetings of four or five technicians for instance. This way the solution can be delivered quickly and there will be possibility for fewer errors.

It will be beneficial to have team work for the LT procedure as well since development of a long-term solution requires cross-competence and people from different departments will have to be involved.

The teamwork outside the LT meeting will benefit the members of the LT procedure due to the same factors mentioned above, less errors and quicker communication resulting in a long-term solution that is delivered faster than before.

7.1.4 STANDARDISED WORK AND KAIZEN IN PROBLEM SOLVING PROCEDURES

Emiliani (2008) argues that standardised work is key practice for implementing Lean. The authors identified the lack of standard in solving problems from the interviews, and the emphasized need for one, hence the expected outcome for this project. A standard is prerequisite for improvement (Emiliani, 2008), thus are standards key for implementing *kaizen*. Since the authors propose a standardised way of proceeding when problem solving, both in need for short- and long-term solutions, it creates a basis for improvements once implemented. Once an improvement suggestion for the procedure has been tested, the members can reflect upon whether it was successful or not in the reflection process that has been introduced in the LT procedure. The effects, if successful implementation, will lead to improved production system performance due to shorter problem solving lead times and higher quality of solution, both short-and long term.

7.1.5 JIDOKA IN PROBLEM SOLVING PROCEDURES

The current MM does have a built-in quality detection, MM7. Even though this is the only person that can detect if a problem solving procedure is good or not, one cannot rely on only one person when discussing *jidoka*. As long as MM7 attends MM, quality detection exists but if MM decides to quit, this will result in o *jidoka* for MM.

For the suggested standard, build-in *jidoka* will only be existent in the LT procedure. This is due to the fact that the ST procedure aims for a quick and remedial action regarding a problem, i.e. quality of the solution is not prioritised. In the LT procedure, *jidoka* will be evident in the test task proposed in the standard where the quality of the solution will be tested. *Jidoka* will lead to solutions of higher quality and to solutions that actually are applicable. Solutions can for instance be feasible in terms of a simplified assembly of the specific component, resulting in a shortened lead time, thus an increase in the production system performance.

7.1.6 GENCHI GENBUTSU IN PROBLEM SOLVING PROCEDURES

The authors have introduced two aspects of *genchi genbutsu*: going to the actual problem to understand it; and attending meetings where the problems are discussed. The reason for why the authors have introduced "go and see", i.e. *genchi genbutsu*, as the first step in the problem solving procedure, both for short- and long-term solutions, is that in order to successfully solve a problem one has to go to the g*emba*, the place of occurrence (Shah, 2017). Therefore, the authors consider both the short- and long-term procedures to fulfil the first definition of *genchi genbutsu*.

The appreciation for the meetings were appraised during the interviews, especially in interviews with GG members. Interviewees from GG said that the meetings is the key for success since the meetings are where all different competences are discussing the same problem. The solution tend to be better when everyone are involved. This is something the authors want to bring forward in the LT procedure where there are different competences and the discussions regarding a problem can lead to successful solutions. By having meetings that are mandatory, people will attend thus fulfilling the second definition of *genchi genbutsu*. The purpose of the ST procedure is to only find a short-term solution so the stoppage in production will end, or eliminate the risk of stoppage. The production planner will attend to be up to date with the on-going problems, while the production technicians are attending to inform about the progress in production and lift problems. The authors consider these people to be the ones necessary for finding a short-term solution, and if help from others is needed they are invited, and therefore will the second definition of *genchi genbutsu* be fulfilled by the ST meeting as well. The first aspect of *genchi genbutsu* is affecting the production system performance negatively because the operator will have to pause the value adding work performed to describe the problem to the technicians. In the long term though, this impact can be neglected since once a problem is solved, it will most likely not occur again. *Genchi genbutsu* as the second aspect, attending meetings, will have a positive impact on the production system performance. When different componence over different departments attend the meetings, the communication will be quicker and the solutions of higher quality, thus improved and quicker solutions implemented leading to an increased production system performance.

7.1.7 PULL/PUSH-SYSTEMS IN PROBLEM SOLVING PROCEDURES

For the suggested standard, the authors have not changed the process of pull- and push systems. For the ST procedure, the push system will be more evident than the LT procedure since the only focus here is to solve problems quickly which means that a solution is necessary as soon as possible. This pushes the problem solving procedure forward, when one step is accomplished, the next must start immediately. For the LT procedure, the push system is still in operation but not in the same scale as the ST procedure. In the LT procedure, the problem solving process will take more time and is not as stressed as the ST procedure. From the operators' point of view, the reporting of an NCR is the start signal for the problem solving procedure hence a pull system. In a problem solving procedure it is beneficial for the solution to be delivered as soon as possible, but this is only a requirement for the ST procedure. This because the production might stop, or already has stopped, and therefore the solution is vital to have fast, hence a higher need of a pull system. For the LT procedure the focus is more on quality rather than fast solutions, therefore the type of system does not matter. Applying a strict pull- or push-system in a problem solving procedure is a difficult task, therefore the authors have chosen to not analyse this further.

7.2 TYPOLOGY OF COMPONENT PROBLEMS IN PROBLEM SOLVING PROCEDURE

This section discusses the first research question "Which type of component problem are resolved by which problem solving procedure?" and elaborates which typologies of problems that can be solved in the suggested problem solving procedure.

As can be seen in Table 4.8 the different, currently used problem solving procedures are taking care of different types of problems, and from the interviews, presented in section 4.2, it became obvious that all three problem solving procedures should solve problems both short- and long-term. The only procedure that actually takes care of problems long-term is GG which has a separate meeting for discussions about long-term solutions. The other procedures, Andon and MM, should take care for both types, but the focus is on the short-term solutions since there is no time for long-term solutions. For MM did the interviewees claim that often short-term solutions, aimed to be temporary, became permanent and long-term solutions, which was not the goal.

Since the suggested problem solving procedure only deals with problems related to TED comparisons will be made with MM which is the only procedure only considering TED currently. The suggested problem solving procedure eliminates the risk of only solving a problem short-term since the short- and long-term procedures are intertwined, which was the case for MM. In addition the typologies of problems can expand further in the future when the suggested problem solving procedure has been in use for a time. This could mean that component problems related to other products in TED's product family can be added or that other types of problems, such as production flow improvements, can be added. The number of problems related to TED will decrease when the long-term solutions have been implemented, since the long-term solutions eliminate the risk of reoccurring problems, and therefore there will be resources available for other types of problems.

7.3 IMPROVEMENT OF PRODUCTION SYSTEM PERFORMANCE

This section discusses the second and fourth research questions and identifies wastes in the suggested problem solving procedure.

Currently the documentation of the time spent per NCR is unreliable, which is discussed in section 5.1. The reported time spent is lower than what it is in reality, and if relying on this information will the problem solving procedure seem to be better than what it actually is. By implementing an extensive time reporting system it will not only be more reliable but it can also be used for analysis. Knowing all steps in the problem solving procedure and the time they take to proceed, one can identify improvement potentials. From improving the time certain tasks take will the problem solving lead time decrease and the solution can be implemented faster in production.

Table 7.1: A summary of actions taken to the wastes in a problem solving procedure.

Waste	**Action**
Inventory	Almost immediate actions to the NCRs
Waiting	Faster communication and more frequent meetings will decrease the answer lead time
Defects	Implementation of testing process
Underutilised people	Involving operators early in the solution development if they would like to be involved. Better documentation of responsibilities and authorities.
Reinvention	Better documentation as well as taking care of long-term problems eliminating reoccurring problems.
Lack of discipline	Implementing a standard for how to proceed a problem and involving the operators.
Limited IT resources	Utilising a digital kanban board suited for managing problems.

The suggested standard consisting of the ST and LT procedure will, in theory, provide a better way of handling the NCRs when the operators write them. When the NCRs are written they will be handled directly by a technician that decides if the problem reported via the NCR should be taken to the ST or LT procedure. This way the NCR will not be idle in a buffer for as long as they are at today. The inventory will therefore decrease and the NCR will be handled much sooner. The authors are aware of the fact that some NCRs still will be idle in a buffer from time to time, due to the fact that the technicians are very busy at times and are not able to handle them directly.

The waiting time will automatically decrease due to the proposed standard which will speed up the process. The technicians know exactly what to do at all times and the communication between the members will increase due to the ST meeting mainly where the technicians meet daily. The daily and weekly interactions will provide better cross-communication between the members which will speed up the communication. The authors are aware of the fact that some waiting time will still exist due to particular factors that cannot always be controlled by the technicians or members of the LT procedure.

Due to the standard, defected problem solutions will most likely not occur. For the ST procedure, errors and defects can most likely occur since the procedure does not have a built-in *jidoka* like the LT procedure does. On the other hand, the authors have not specified any requirements on the problem solution regarding the ST procedure, only that the procedure delivers solutions quick. If the solution is a good one or not is not very important, as long as it works. On the LT procedure however, the requirements are that a long-term solution is provided that is the right and best one for the specific problem. Also, the LT procedure does have a built-in *jidoka* quality detector in the form of a testing process. Due to this, the authors expects the LT procedure to deliver faultless solutions.

When implementing *genchi genbutsu*, as going to the actual problem and talking to the one reporting the problem, the possibility to include the operator in the problem solving procedure improves. General responsibilities, such as which production technician is responsible for which parts in the product, should be decided upon before the meeting and documented. Each person attending the meeting has a responsibility, and what this is should be documented on beforehand. Whenever there are uncertainties about who should be responsible this document can be revisited. Authority is managed at an organisational level, and therefore this is a waste that will remain in the future problem solving procedure.

When implementing the new suggested standard at DSC, documentation and knowledge, of the technicians mainly, will increase. The communication will improve drastically due to the *kanban* boards that will be implemented for the ST and LT procedures. The standard also states that feedback to the *kanban* boards must be provided after each step in the problem solving process. This way documentation will be prioritised and time will be spent to actually write detailed information about what has been done and what is still to be done will be written down. The standard will also ease the learning for the technicians. The technicians do not have to put energy and thought into what should be done next. Instead, the standard will provide them with information on what to do each step until the solution is complete. Knowledge about the product comes from involving the ones knowing the product, i.e. the operators.

The standard will also reduce the wastes created by lack of discipline. The goals will be clearer since the communication will be better. This way the technicians can have different responsibility areas as long as the communication is good between the different procedures and their members. The authors recommend the technicians to work according to some kind of schedule due to discipline matters. Otherwise, the technicians can easily be interrupted with other work that maybe is not as important as solving problems related to TED, especially the technicians working in the ST procedure where discipline is needed to resolve problems quickly and not be distracted.

Since the authors suggest to remove the OneNote file and replace it with a digital *kanban* board will the capability and compatibility increase. On the *kanban* board, each card represent a problem, where the people can update by attaching additional files or link to e-mail conversations or write a comment, which will increase the capability and compatibility, as well as increase the detail of information.

All information about the problem will be gathered in one place and the information can be everything from a link to a root-cause analysis to ”waiting for answers regarding changes from supplier”. This leads to everyone being up to date about the problems they are involved in and the new information can be available even before the next meeting. This would mean that the next steps can be taken much faster, leading to reduced problem solving lead time. A reduced problem solving lead time will in turn lead to implementing the solutions faster in production and this will increase the production system performance.

Since the authors was not able to trust the NCR numbers for calculating the current impact of the current production system performance, no assumptions on how much better the future state problem solving problem solving procedure can be made. If consistent NCR numbers were to exist, the effect on the current production system performance could be calculated and lay as a basis for the improvement suggestion. Since this is not the case, the authors can discuss about how much the new problem solving procedure will improve the production system performance from the perspective of the two procedures.

If assuming that a problem was solved long-term, it should not occur again. From this assumption, the authors can forecast that the problems related to TED will decrease with time. If the problems related to the product TED decreases, the disturbing factors affecting the production system performance will decrease, resulting in higher production system performance. This also means that the ST and LT procedures will have less problems to solve with time which is interpreted as positive effect by the authors.

The NCR system will be used like it is today. The only differences are that the operators must write NCRs on exactly everything and the information in the NCRs will not be as extensive as it is today due to easier reporting system. The NCR system is the best way for the technicians to know what problems exists in production. Unfortunately, many operators today ignore to write NCRs because they do not feel like writing the same NCR over and over again when nobody takes care of them. With the suggested new standard with two procedures, problems will should not reoccur since two procedures are designed to handle both short- and long-term problems. The two procedures will pay attention to all emerging problems in production, something that did not exist before due to MM mainly solving the problems short-term.

The NCR system will be one way for the technicians to know how severe the problem are in production and how frequent they are. Also, when the NCRs for one specific problem decreases or, in best case scenario, stops completely the technicians will know that their solution is working. It will be as used as a feedback system for the technicians and the technicians will work as a feedback system for the operators by entering production and letting them know about their solution.

7.4 VALUE STEAM MAPS FOR PROBLEM SOLVING PROCEDURES

The VSM-tool displayed both advantages and disadvantages when applied in the current study. Due to the fact that the VSM tool is based on the processes and their timespans, the VSM could not be completed due to the lack of data about the problem types. The VSM is beneficial to use when rich data about the concerned processes is available, but such rich data was not available at the DSC. Except for this, the VSM tool has been beneficial to map and visualise the current state processes and the future suggestion for standardised work. Locher & Keyte (2016) argue that it can be hard to identify and apply lean practices for a nonproduction area, which also was encountered during this study. Many of the lean practices had to be modified and adapted, such as *genchi genbutsu*, in order to make sense for the application in problem solving procedures. Rother & Shook (1999) explain VSM as a tool for visualising and analysing both quantitative and qualitative data. The authors would argue that this would be the case if DSC were better at documenting the progress of previous solved problems.

The authors have also understood that for administrative process it is common to lack information about the processes as Locher & Keyte (2016) state. This information was obtained from the interviews with the workers at DSC and from observations while participating in the different meetings. Barber & Tietje (2008) identified challenges when mapping the sales process, the authors have identified similar challenges, such as:

- Variations in the process dependent on the people, the problem and no standardised way of working, in addition were the documentation of already solved problems were poor.
- The issue of not having a specific product to follow, but a problem specific solution.
- The need of redefining the value-adding and non-value adding work in the problem solving procedure.

Due to the troublesome documentation for the process, the authors made several assumptions based on interviews and observations, throughout the mapping of the current processes. The authors have made assumptions on the steps in the process that should have been performed, and most likely where, in the process. Most of the assumptions have also been validated through emails to the responsible people for the related problems. Finding the responsible people for the problems was a struggle itself since not many problems have a documented responsible person and due to this, some problems could not be validated.

The authors decided not to include the timeline in the future state VSM since the new standard has not been tested in any way when this report is written. The authors consider to not have enough information about the current problem solving procedures for basis of making reasonable assumptions. Due to this, no timeline has been added, neither to the short- nor long-term procedures.

The value stream mapping is a great tool in the authors' opinion if relevant information exists. Otherwise, VSM is difficult to complete due to lack of information for administrative processes.

7.5 THEORETICAL CONTRIBUTION

The theoretical contribution has been touched upon previously in this chapter while discussing the results. This section will therefore summarise the main aspects of theoretical contribution.

This thesis contributes with an understanding of how Lean practices and tools can be applied to problem solving procedures as a means to improve the production system performance in advanced technology manufacturing. Lean has been applied in various contexts previously, but this project adds to the context outside of the automotive industry, hence in a context of administrative and creative process where the quality levels are high, the products are complex and high secrecy levels are applied. This leads to an adaptation of not only the practices but also the tools applied throughout the project.

7.6 PRACTICAL CONTRIBUTION

The practical contribution is a standard for how to approach component problems in advanced technology manufacturing. How this standard contributes to DSC can be read previously in this chapter, while this section will summarise the main contributions to DSC.

DSC will first of all notice, when the standard has been implemented, an improved way of solving component problems related to TED, which in turn will lead to a decreased production lead time due to a reduced problem solving lead time. The problems will no longer only be solved short-term with temporary solutions becoming permanent, but the problems will also be solve long-term with high quality. This eliminates the risk of having reoccurring problems, hence will the production never be stopped more than once for the same problem and the number of problems will steadily decrease. Therefore can the production system performance increase. Additionally, the standard lays ground for training for beginners, better documentation and communication and continuous improvement of the problem solving procedure.

7.6.1 RECOMMENDATIONS FOR IMPLEMENTATION AT DSC

Kotter (2017) suggests following an 8-step model when implementing a change, which will be the case when DSC decides to implement the suggested problem solving procedure. Kotter's 8 steps are (Kotter, 2017):

1. Create a sense of urgency
2. Build a guiding coalition
3. Form a strategic vision and initiatives
4. Enlist a volunteer army
5. Enable action by removing barriers

6. Generate short-term wins
7. Sustain acceleration
8. Institute change

The authors consider the first step to already be fulfilled in the sense that DSC themselves initiated the project for the thesis and all people working with problem solving regarding TED feel that the current situation is unbearable. The next step is to create a guiding coalition and Kotter (2017) recommend for small organisations, which is the case for DSC and TED, to be a team of three to five members. Therefore do the authors consider the technicians to be the guiding team, with extra help from the team leader to communicate this to higher management. The third step is to create a vision, and that basically should mean that the vision should be that all problems related to TED will follow the suggested procedure, but there has to be smaller steps in the vision. One first small vision could be to implement the suggested *kanban* boards and have the meetings up and running. These small visions are to be used as a roadmap to meet the main vision. Enlist a volunteer army is to get all people aboard (Kotter, 2017) and this should be to higher management but also the operators. To do this information about the change process has to be shared, not only to primary stakeholders (e.g. the one in the problem solving procedures) but also to the secondary stakeholders (e.g. the operators). The fifth step is about removing the obstacles that are hindering the procedure to be fully implemented, and this could be the digital *kanban* boards as well as not having the correct instruction for how to write an NCR for the operators. These obstacles have to be identified by the technicians working the environment daily, once identified they can be removed. The short-term wins are a way for management to see clear performance improvements and once a performance measure is reached there are some reward to the people in the process (Kotter, 2017). These short-term wins should be determined by the management, but the goals should be set in collaboration with the people in the suggested procedure. By "sustain acceleration" does Kotter (2017) mean to not celebrate success to early which has a tendency to make the progress to stop. Instead Kotter (2017) recommends to celebrate the small wins from time to time, which goes hand-in-hand with Toyota vision which is to aim for perfection and never satisfy since there is always improvement potentials. The last step is to acknowledge the changes in both culture and performance and to understand why the outcome is what it is (Kotter, 2017). This is purely a reflection phase where the people involved understand the connections between their behaviours and the performance and learn from it.

7.7 Generalisability

The suggested problem solving procedure is very general and not heavy on details only applicable for DSC and TED. Therefore the procedure can be applied in other environments as well. For TED the problems are identified in the production unit, but the task of *genchi genbutsu* can be to go wherever the problem is identified. The typology of problems is not tied to components only, thus can other types of problems can be solved via the same problem solving procedure design. One example could be for improvements in production flow. This problem will be considered as long-term problem since it does not create a risk for stoppages in production. A new layout might be developed through the steps in the procedure and then implemented. Another example would be if a tool breaks down. This will be treated as a short-term problem, since it can stop production.

The suggested problem solving procedure might not be applicable in all contexts, such as high volume production. In high volume production are the production stoppages more severe since the production lead time is much shorter than in advanced technology manufacturing. One thing that should be considered in all contexts is the focus on having high quality solutions and a reflection process for long-term solution development. All organisations benefits from having a reflection process where the problem solving procedure is reflected upon and successes and failures will be lifted for self-development.

The authors would argue that the suggested problem solving procedure can be applied in all types of low volume production, where the problems are found during control or assembly and the production technicians are the responsible for solving the problems.

7.8 Sustainability aspects

The suggested problem solving procedure have been developed with a sustainability aspect. The authors have considered economic, environmental and social sustainability for the development.

The new problem solving procedure will improve the economic sustainability since the authors are convinced that the problem solving lead time will decrease. Therefore will the production stoppages be shorter and DSC is coming closer to meeting the market demands in number of units as well as having a downtime cost reduction. The new problem solving procedure will make sure that there is a focus on the long-term solutions, which in turn makes sure that problems are reoccurring. From this it becomes easier to truly meet the market demands. Once most problems are eliminated there is a possibility to focus on decreasing the production lead time, if the market demands require so, hence improving the business growth. Today temporary solutions, which often involves rework of components, have become permanent solutions since a long-term solution has not been prioritised. In the new problem solving procedure this will not be the case. Reworking components are often requiring additional energy consumption as well as causes a lot of scrap. If the long-term solution is found this will be eliminated, hence being more environmental sustainable.

Social sustainability include components regarding labour and stakeholders, and satisfaction of these. The labour mainly in charge of solving problems are the production technicians at DSC, and they have spoken their mind about being frustrated about the current problem solving procedure. The technicians are claiming not to know when approaching a problem, and at the same time they should report to upper management about the proceeding. There is always an insecurity of if one is doing the right thing or not. With the new problem solving procedure will the progress be reported more often and other people can give a heads up if the progress is going in the wrong direction. In addition there will not be a question in what to do since there is a standard to rely on. One of the stakeholders is the end customer of TED. They are satisfied when products are delivered on time and with highest quality. This is achieved when the problem solving procedure has been implemented in the long run. The quality of the components will increase since there is a long-term solution that is actually tested, and the number of problems will decrease which will make sure that DSC is delivering the product when they have promised.

7.9 Further research recommendations

The case study was considered appropriate for answering the research questions during the time period. To identify the impact that the proposed problem solving procedure has on the production system performance it has to be implemented. The analysis of the application of different Lean practices in the currently used problem solving procedure and the suggested standard taking same Lean practices into consideration seem to be applicable for the actual case company and the product it refers to.

Problem solving procedures may differ among other organisations as well as among different purposes, so the authors would argue that the findings are case specific but adaptations of them can be applied to other organisations and purposes. In addition it would be of interest to investigate what changes in the culture would be needed for a successful implementation of the new standard.

Further research would be to study if the suggested standard can be applied to other departments within the same organisation, and if it, later on, can be applied to a completely different organisation. The case company has a low volume production, it can be of interest to see how the problem solving procedures affect the production system performance in a high volume production. In addition, it would be of interest to analyse how Lean practices are applied to problem solving procedures in a truly Lean organisation. Furthermore, investigation of how technology trends, such as Industry 4.0 and Internet of Things, affects the problem solving procedures related to production.

8 CONCLUSION

In this chapter will the conclusion of the thesis and a summary of the answers to the research questions presented. Furthermore is the contributions and future research recommendations summarised.

This thesis has studied how the production system performance can be improved by means of enhancement of problem solving procedures for components in advanced technology manufacturing. The thesis applied case research in order to answer four research questions related to the current problem solving procedures of one product, product TED, and development of a new problem solving procedure related to TED. It was found that currently there are three problem solving procedures; Guldgruvan with managers related to all production in-house, Andon with two mechanical design engineers, and Materialmötet with all white collars related to TED. Further the four research questions will be answered.

RQ1: Which type of component problem are resolved by which problem solving procedure?

Problems affecting open orders, thus having the possibility of not deliver on promised date, are discussed in the Guldgruvan procedure, where the meetings have competences from various departments for effective operations management. Guldgruvan claimed to be used for operations management, not a specific problem solving procedure. Problems related to the design of all products being ready to produce in-house are solved via Andon procedure. All different types of problems related to TED are solved via Materialmötet where all affected departments are represented.

RQ2: What impact do component problems and their associated problem solving procedures have on the production rate?

On average it takes 13 weeks to solve a problem related to TED via Materialmötet, which correlates to a production stoppage of the concerned unit for 13 weeks. If the component problem relates to several units, all units are stopped for the same amount of time. This hinders the product unit to proceed in the production system, hence decreasing the production rate over this period of time.

RQ3: How are Lean practices applied to the currently used problem solving procedures?

The assessed Lean practices were: *shu-ha-ri*; catch-ball process; *yokoten*; *kaizen*; cross-competence; standardised work; *jidoka*; and *genchi genbutsu*. It was concluded that Guldgruvan were the procedure applying most Lean practices, six out of the nine practices. Andon applied two out of the nine assessed Lean practices, while Materialmötet applied three out of the nine practices. It was concluded that there were possibilities of improvements for all procedures.

RQ4: What problem solving procedure design would improve the production system performance over the procedures used in the current state?

A problem solving procedure design were there are two different procedures for short- and long-term problems would be beneficial since currently the short-term solutions, that should be temporary, have become long-term solutions and permanent. By implementing a standard to rely on in the procedure and having more frequent meetings the problem solving lead time should decrease, thus decrease the time of the production stoppage. By taking care of a problem in a long-term procedure will the possibility for the same problem to reoccur be eliminated.

The purpose of identifying how the problem solving procedures affect the production system performance currently has been fulfilled by answering RQ1, RQ2 and RQ3, while the aim of developing a standard for a more effective future problem solving procedure has been fulfilled by answering RQ4. The thesis contributes to how Lean practices and tools can be applied to administrative and creative processes, in the development of a Lean enterprise. For the case company the contribution is a standard for how to resolve component problems and when implemented an increased production system performance.

Further research would be to identify how technological trends, e.g. Industry 4.0 and Internet of Things, could affect the problem solving procedures in advanced technology manufacturing. In addition, a comparison of how Lean practices are applied to problem solving procedures within other organisations, such as high volume production and other manufacturers, could be performed.

The authors have concluded that an adaptation of Lean practices and tools can be applied to administrative and creative processes, but further investigation and benchmarking has to be performed.

This thesis has been a great lesson in how to adapt Lean practices, usually found in manufacturing processes, to administrative processes and how Lean tools can be applied to visualise these types of processes.

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APPENDIX A

Hej och välkommen, varsågod och ta fika.

Som vi nämnde i mailet så är vi två exjobbare på DSC som har fått i uppgift att förbättra lösningsprocessen för TEDs komponenter. Under intervjun vill vi däremot att du tänker/svarar generellt för dem områden som du arbetar med.

I rapporten kommer du självklart vara anonym, men går det bra att vi spelar in intervjun och transkriberar den? Detta kommer underlätta för oss. Vill du validera transkriberingen så kan vi skicka den till dig när den är klar?

Redo?

1. Vad är syftet med er kanal?
2. Vad är din roll i XX-kanalen? (utanför?)
3. Hur ofta har ni möten och vad gör ni på dessa?
4. Hur får ni reda på problemen?
5. Hur många produkter tas upp i kanalen?
6. Vad är det som gör att de hamnar hos er istället för någon av de andra kanalerna?
7. Har ni någon mjukvara för att hålla reda på problemen och uppdatera dem? Vi vet att både JIRA och OneNote används, vilket använder ni?
8. Hur prioriteras problemen? Vem gör prioriteringen? Hur görs prioriteringen?
9. Om ett problem inte prioriteras eller att er kanal inte hanterar problemet, vart hamnar problemet då?
10. Hur bestämmer man vem som tar sig an respektive problem?
11. Hur arbetar ni vidare med problemen utanför möten?
12. Jobbar ni med långsiktiga eller kortsiktiga lösningar på problemen?
13. Finns det något slags teamwork mellan er i kanalerna även utanför mötena?
14. Hur många problem tas upp i kanalen per månad ungefär?
15. Hur lång tid tar det att lösa ett problem i kanalen?
16. Vem levererar ni problemlösningen till?
17. Tror du att ert arbetssätt skiljer sig mot de andra kanalerna?
18. Har ni något standardiserat arbetssätt dokumenterat?
19. Upplever du att ert sätt att arbeta är optimalt? Om inte, vad skulle kunna göras bättre?
20. Använder ni någon slags känd arbetsform som du känner till? T.ex. Scrum och Agile?
21. Hur många av kanalens medlemmar är även med i andra kanaler?

Tack för alla bra svar. Vi ska sammanställa alla intervjuer och analysera dem för att kunna skapa en gemensam bild av hur ni upplever att ni arbetar. Vi kommer sedan ha en workshop där vi presenterar vad vi har kommit fram till. Det vi vill då är att ni bekräftar om det är en rättvis bild eller inte. Vill du medverka på denna? Tack så mycket för din tid!

APPENDIX B

Hej och välkommen, varsågod och ta fika.

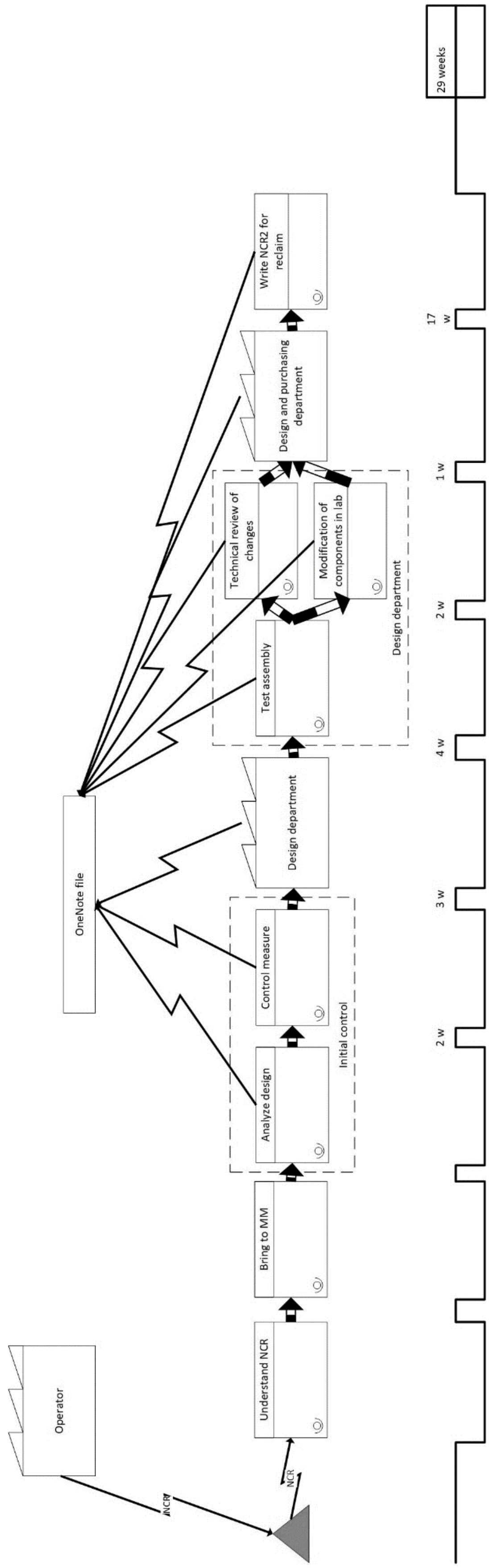
Som vi nämnde i mailet så är vi två exjobbare på DSC som har fått i uppgift att förbättra lösningsprocessen för TEDs komponenter. Under intervjun vill vi däremot att du tänker/svarar generellt för dem områden som du arbetar med.

I rapporten kommer du självklart vara anonym, men går det bra att vi spelar in intervjun och transkriberar den? Detta kommer underlätta för oss. Vill du validera transkriberingen så kan vi skicka den till dig när den är klar?

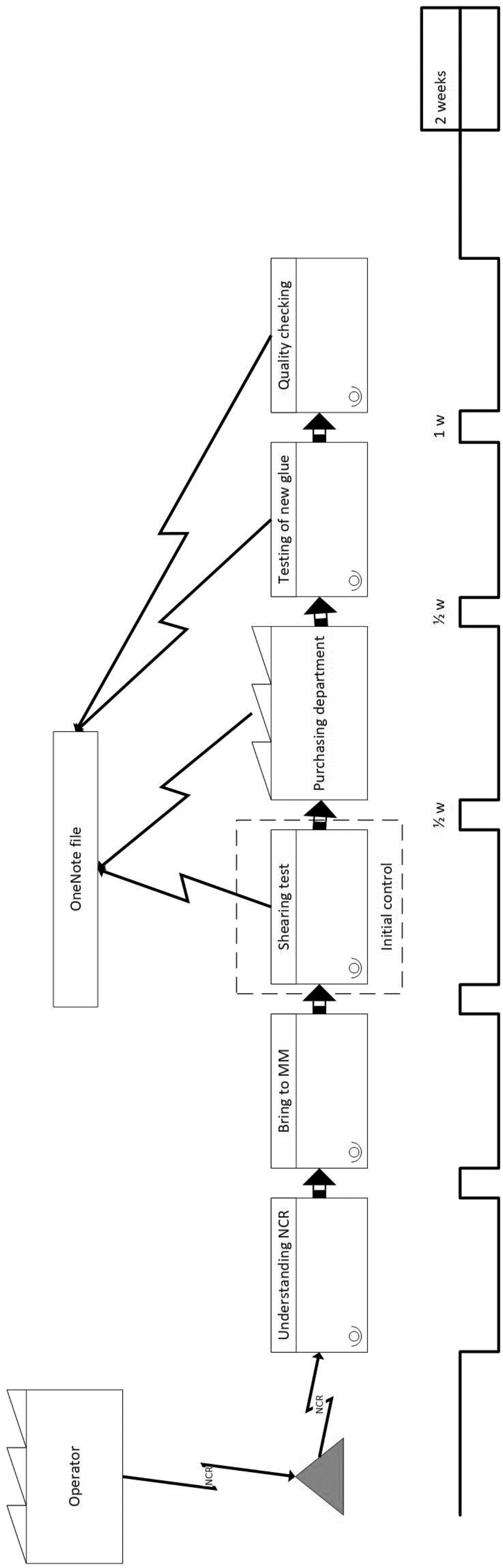
Redo?

1. Vad gör du inne på produktion?
2. Ledtid på felfri TED?
3. Hur ofta händer detta?
4. Faktisk ledtid (d.v.s. inklusive fel)?
5. Vad händer när ni hittar ett fel i produktion?
6. Vad händer sedan?
7. Hur vet man vilket problem som ska rapporteras vart?
8. Är ni på något sätt involverade efter att en felrapportering skrivits?
9. Kan du förklara?
10. Vad undviker man att göra felrapportering på och vad löser man själv?
11. Hur lång ledtid har problemlösningen?
12. Vad händer med produkten under tiden ett problem löses?
13. Vem är det som orsakar flest produktionsstopp? Leverantörer eller vi själva?
14. Vad är orsaken till att produktion genererar produktionsstopp?
15. Vilket fel leder till längst produktionsstopp?
16. Hur lång tid varar ett produktionsstopp i medel?
17. Har ni något intern möte inne på produktion?
18. Vad tas upp?
19. Vad tycker du om månadsgenomgång av NCRerna?
20. Tror du att det är ett forum där ni kan bli mer involverade i lösningsprocessen?

APPENDIX C

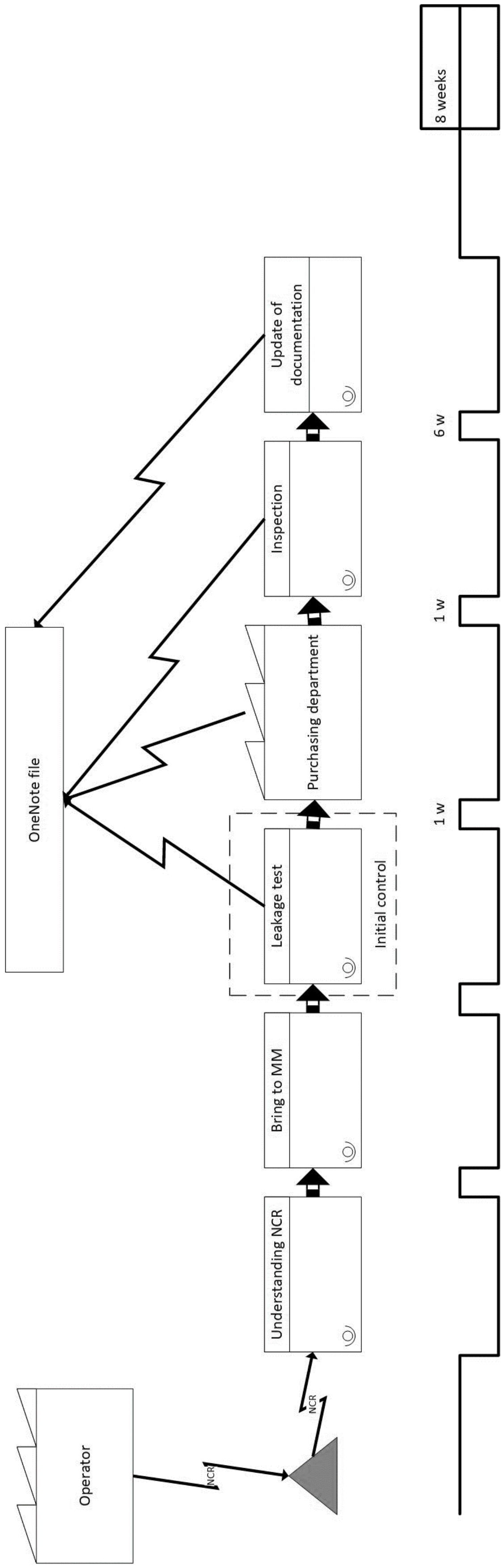

Operator
NCR
NCR
Understand NCR
Bring to MM
Analyze design
Control measure
Initial control
Design department
OneNote file
Test assembly
Technical review of changes
Modification of components in lab
Design department
Design and purchasing department
Write NCR2 for reclaim
2 w
3 w
4 w
2 w
1 w
17 w
29 weeks

APPENDIX D

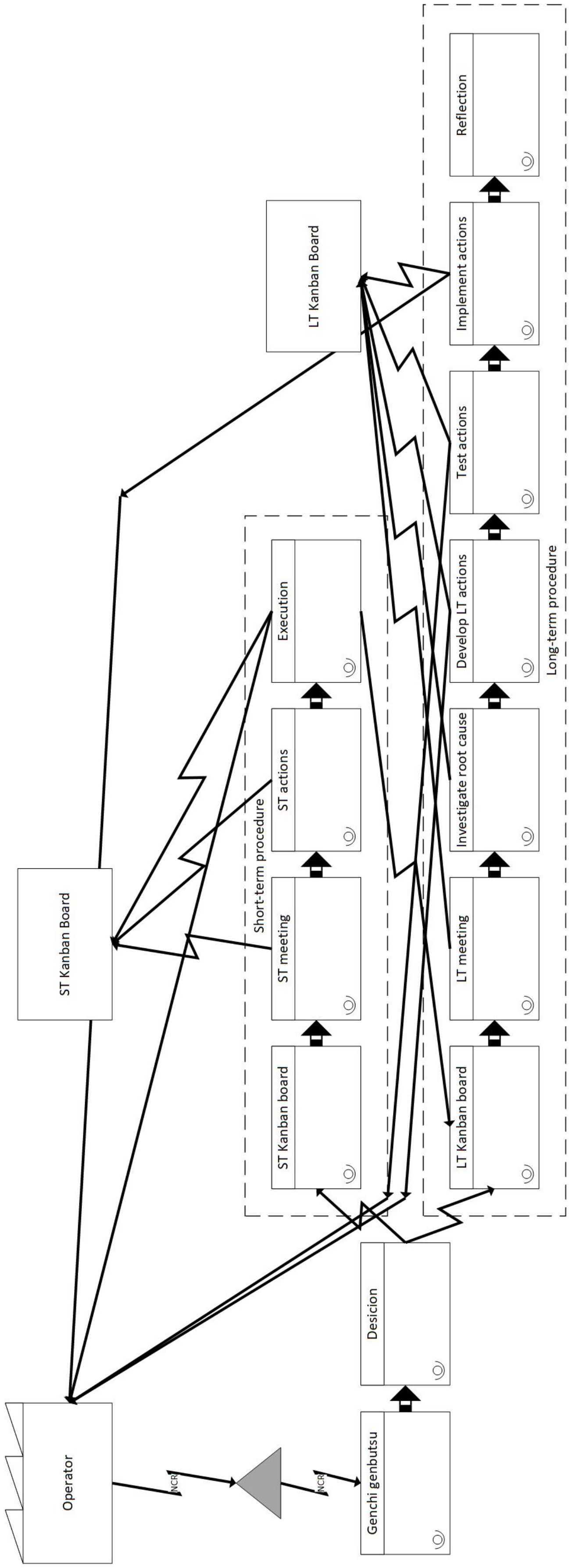


Operator
NCR
NCR
Understanding NCR
Bring to MM
Shearing test
Initial control
Purchasing department
Testing of new glue
Quality checking
OneNote file
½ w
½ w
1 w
2 weeks

APPENDIX E


Operator
NCR
NCR
Understanding NCR
Bring to MM
Leakage test
Initial control
Purchasing department
Inspection
Update of documentation
OneNote file
1 w
1 w
6 w
8 weeks

APPENDIX F



LT Kanban Board
Reflection
Implement actions
Test actions
Develop LT actions
Investigate root cause
LT meeting
LT Kanban board
Long-term procedure
Execution
ST actions
ST meeting
ST Kanban board
Short-term procedure
ST Kanban Board
Desicion
Genchi genbutsu
Operator
NCR
NCR

APPENDIX G

Suggested standard of tasks presented to DSC

Make a decision

1. Operator discovers a problem - reports it
2. Problem will be put in buffer
3. Technician go and see understand whether it is production or elsewhere
4. Ask the following questions to the operator:
    4.1. When did you discover the problem?
    4.2. How did you discover the problem?
    4.3. What is normal?
    4.4. Why did it happen?
    4.5. Do you have a suggestion on a solution?
5. Technician decides whether it should be brought to ST or LT
6. Technician puts it on either ST or LT

ST procedure

1. Problem uplifted at daily ST meeting
2. Updates Kanban board ST
3. Short-term actions are discussed and taken
4. Updates Kanban board ST
5. Short-term solution is executed to firefight
6. Updates Kanban board ST
7. Kanban card moved to LT kanban board
8. Updates operator

LT procedure

1. Technician works on the problem if possible, does not wait to the weekly meeting
2. Problem uplifted at LT
3. Update Kanban board LT
4. Investigate root cause following 5-Why
5. Update Kanban board LT
6. Develop Long-term actions
7. Update Kanban board LT
8. Update operator, ideas?
9. Test of developed actions
10. Update Kanban board LT
11. Update operator, ideas?
12. Implement long-term actions
13. Update Kanban board LT
14. Update operator
15. Technicians reflect - What have we learned?