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LEAN SIX SIGMA METHOD APPLIED FOR INCREASING TRANSPARENCY

Case: Company X Optimizing the Repairing Process in the Production Line

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NIUTANEN, ANNA-MARI:

Lean Six Sigma metodin soveltaminen läpinäkyvyyden saavuttamiseksi

Yritys X Korjaus-prosessin optimointi tuotantolinjalla

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TIIVISTELMÄ

Tämä opinnäytetyö dokumentoi toimeksiantajan Yritys X Six Sigma projektin vaiheet, antaa suosituksia, kuinka prosessia voidaan parantaa ja jatkotutkimusehdotuksia. Tutkimuksen päätavoitteena on tehdä tuotantolinjan korjausprosessista läpinäkyvämpi informaation jakamisen ja tietojärjestelmien näkökulmasta.

Kvalitatiivinen aineisto kerättiin havainnoimalla ja haastatteluilla. Kvantitatiivinen aineisto tilastollisia analyyseja varten otettiin yrityksen SAP iPro tietopankista. Tutkimus koostuu teoria ja empiria osuudesta. Teoriaosuudessa käsitellään tilaustoimitusketjun ja informaation hallintaa sekä Six Sigma projektimetodin vaiheet caseosuuden teemojen mukaisesti.

Tutkimus osoittaa informaatiosysteemien ja kommunikaation merkityksen tilaus-toimitusketjussa. Sen lisäksi, tiedon läpinäkyvyys ja jakaminen yksinkertaistavat monimutkaisia prosesseja. Varaston ja kuljetuksien hallinta on tasapainoilua sisäisten ja ulkoisten odotusten ja vaatimuksien välillä.

Tutkimus esittää seuraavat kolme tekijää merkittävimmiksi läpinäkyvyyttä tuoviksi tekijöiksi. SAP:in puuttuvat kentät tulisi aktivoida tiedon laadun parantamiseksi. Kuukausittaiset poikkiorganisatoriset kustannus- ja volyymi-analyysit sekä tiedonjaon syventäminen ulkoisten tavarantoimittajien kanssa toisivat toivottua läpinäkyvyyttä korjausprosessiin.

Tärkeimmät elementit prosessin hallinnassa ovat selkeä työnjako, informaation jakaminen ja näkyvyys, yhteistyö ulkopuolisten toimijoiden kanssa sekä poikkiorganisatorinen yhteistyö.

Asiasanat: Lean Six Sigma, Tilaus-toimitusketjun hallinta, Tiedonhallinta, Tiedonjakaminen, Läpinäkyvyys

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Lean Six Sigma Method Applied for Increasing Transparency

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ABSTRACT

This thesis documents the different phases of the Six Sigma project for the commissioning company Company X and gives recommendations on how the repairing process can be improved and suggestions for future research. The main objective of this thesis is to increase the transparency in the repairing process in the production line from the perspectives of information sharing and information systems.

The author applies mixed research methods in this study. Qualitative data is collected by observing and informal conversational interviews. Quantitative data for statistical analysis is taken from the company's SAP iPro database. The study consists of theoretical and empirical sections. The aim of the theoretical part is to give a review about the supply chain, information management and Six Sigma project method, according to the themes of the case study.

The study addresses the meaning of communication and information systems in the supply chain. Moreover, information transparency and information sharing simplify complex processes. Warehouse and transportation management is abalancing act between internal and external requirements and expectations.

The research proposes activating the untapped SAP fields in order to improve data quality, monthly costs and volume analysis as a cross-organisational action, and finally, to deepen cooperation and information sharing with external suppliers.

In conclusion, clear roles, data quality, information sharing and visibility, cooperation with external partners and cross-organisational cooperation are the key elements in process management.

Key words: Lean Six Sigma, Supply Chain Management, Information Management, Information Sharing, Information Visibility, Transparency

APPREVIATIONS

ANOVA	Analysis of Variance
BANF	Bestellanfordeung
	Requirements for the Order to Repairing
BEST	Bestellung zur Reparatur
	Order to Repairing
CL	Central Line
DoE	Design of Experiment
LSL	Lower Specification Level
MSA	Measurement System Analysis
NPM-Lager	Lager für nicht produktives Material
	Warehouse for non-productive Material
PCA	Process Capability Analysis
SAP iPro	Systems, Applications and Products in Data Processing
SIPOC	Supplier, Input, Process, Output, Customer
USL	Upper Specification Level

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1 INTRODUCTION

1.1 Background of the Thesis

> *"Organizations view their supply chains and networks as critical determinants of efficiency and effectiveness in the face of rapidly changing and competitive business environments, short product lifecycles and rapid market fluctuations" (Goswami, Engel, Krcmar 2012, 276.)*

Supply chains and networks have an important role in companies. In order to manage this all, companies need teamwork and projects to optimize processes and networks in the supply chain.

According to Jones Womack, blaming people does not improve uneffective processes (Womack 2005, 47). On the other hand, recruiting the right people with the right skills is the vital element in creating a lean process in the company (Womack 2005, 75-77). This aspect applies to external suppliers as well. The companies need to find out, which suppliers are capable of delivering cost effectively, good quality in short lead-time. (Fredendall, Hill 2001, 149-150.)

Six Sigma is a registered trademark and service mark of Motorola, Inc. (Minitab, Inc 2009) Six Sigma is a project method that aims to create lean processes. When explaining Six Sigma, there are two central concepts. Firstly, there is an overall thinking that everything is a process, also people's every day life with small decisions. Secondly, the output or performance must be measurable. (Windsor, S 2006, 1-3.)

The idea for this thesis came up during the internship, which the author was doing in the department A in Company X in spring 2014. Because of the number of interesting themes in the project, the author decided to choose one of these topics for the bachelor thesis. The author was working on a Six Sigma Project about Repairing Process Optimization. The process is not a value adding process from the end customer's or product's point of view but it is important from the plant's point of view. In other words, the repairing process is not for the end products vehicles; it is for the machines and robots in the production line. For example when a motor of a robot in the production line breaks down, the employee in the production line brings the motor into a NPM warehouse. The NPM warehouse is a stock for non-productive material. In other words, it is a warehouse, in which there are no parts for the actual end products, automobiles rather for the machines in the production line. (SAP Specialist Planing 2014)

The project team consists of employees from the department A. In the following figure 1, there are presented the internal and external operative parties and customers of the repairing process.

FIGURE 1. The Parties of the Repairing Process.

The department is responsible for the repairing process and improvements in it. The management team tends the budget and other administrative aspects of the process. Thus, they are the customers of the project; they aim for time and cost effectiveness and transparency in the process. The operative parties of the repairing process are the employees in the NPM warehouse, the external suppliers and employees in the department. The external suppliers repair the spare parts from the production line. The employees in the department are experts in the information systems, which are used in the company. The customers of the process are the employees in the production line; they need a new or repaired spare part back as soon as possible, in order to avoid delays in the production line of the end commodities. (SAP Specialist Planing 2014)

In addition, the customers in the production line are divided in three levels: there are technical experts, maintenance employees and the basic employees in the production line. Figure 2 below shows the hierarchy between these three levels.

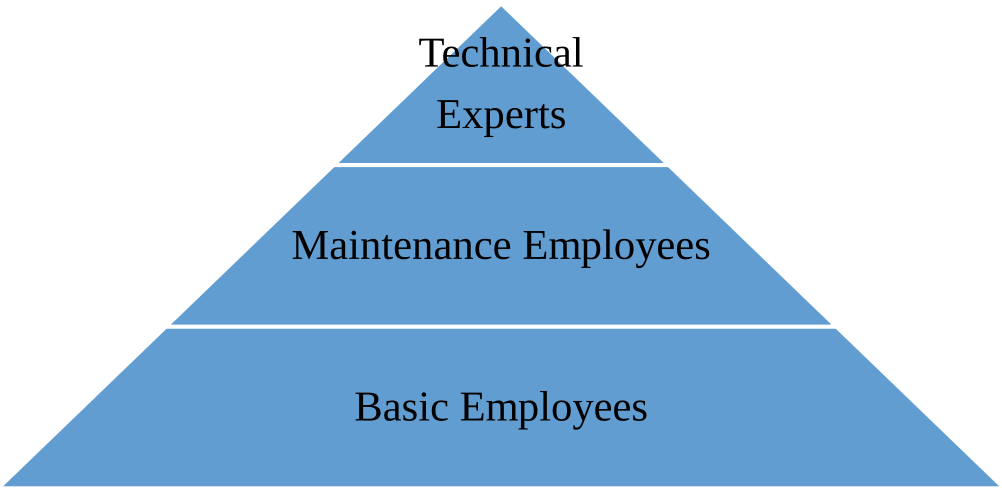

FIGURE 2. The Hierarchy between the Employees in the Production Line

In other words, technical experts have the technical knowledge about the production line and maintenance employees look after the maintenance of the machines and robots. The basic employee is a term the author uses for the regular employees working in the production line. (SAP Specialist Planing 2014)

1.2 Research Question, Objectives and Hypothesis

This thesis is based on the Lean Six Sigma project called Repairing Process Optimization in Company X. The goals of the project are to increase transparency and cost and time effectiveness in the repairing process. This, on the other hand, allows the department, especially the management team, to have a better control of the process. The main topic in this thesis will be on transparency in the information flow of the supply chain. The special focus will be on the information sharing and information systems such as SAP databank.

The main research question of this thesis is:

> How to increase information transparency in the repairing process of the spare parts in the production line in Company X.

There are some secondary questions to help to focus the main research question:

- How does Company X use the Lean Six Sigma method?
- What elements do cause less transparency in the process?
- How can the repairing process be improved through the project?

The first secondary question is chosen to show, how the case company applies the Lean Six Sigma method in practice. The author has been quite independently responsible for the project management and the usage of Lean Six Sigma method. The last two secondary questions concentrate on the narrower topic stated in the research question. Consequently, in this thesis, the author emphasizes the information transparency some hypothesis in mind.

Hypothesis:

- Problems in the information flow cause less transparency.
- Because of less transparency the process is not cost-effective.
- Because of less transparency the lead-times are longer.

To these hypothesis the author aims at to answer in the conclusion of this thesis.

1.3 Limitations of the Thesis

Due to the large amount of aspects in the project, there are limitations to this thesis. Firstly, as stated in the first sub-chapter, the repairing process is not for the company’s end products. The project considers only non-productive material in the production line. Secondly, in figure 3, it is possible to see the very simplified repairing process flow and its relation to the purchasing process and inventory levels.

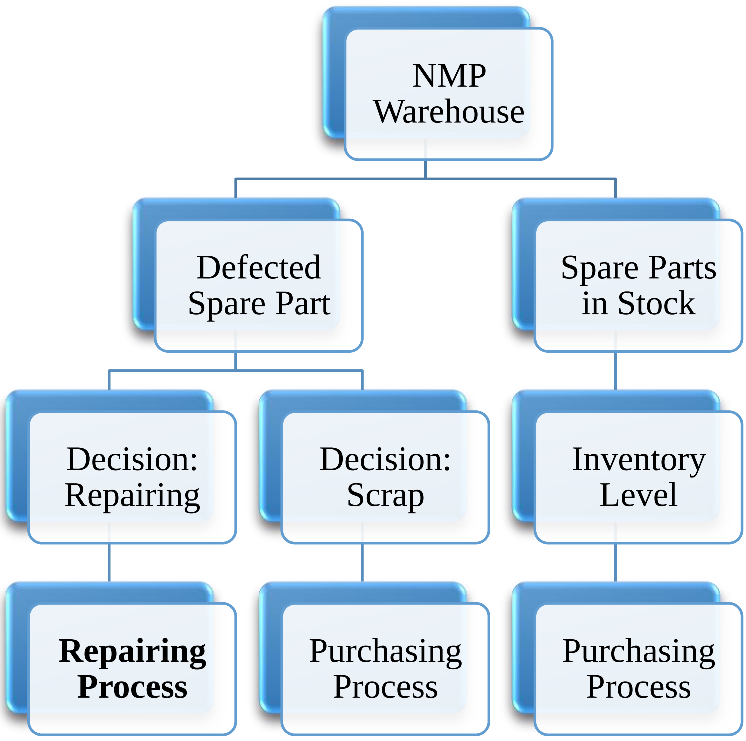

FIGURE 3. Processes Related to Repairing Process.

Firstly, there are two ways to fulfill the customer need in the production line: the defected spare part is either repaired or the production line is given a new part. The defected part is repaired through the repairing process. A new spare part is bought through the purchasing process. The two processes are closely connected to each other, but in this thesis the purchasing process is excluded. The emphasis is on the repairing process. Secondly, some of the spare parts need to be in the NPM stock to avoid delays in the production line. The inventory levels in the NPM warehouse were analysed during a previous project last year. Therefore, the in-depth analysis of the inventory levels in the NPM warehouse is excluded from the project and from this thesis.

Finally, as stated in the previous sub-chapter, the project has a few goals. In figure 4 below, the goals are stated.

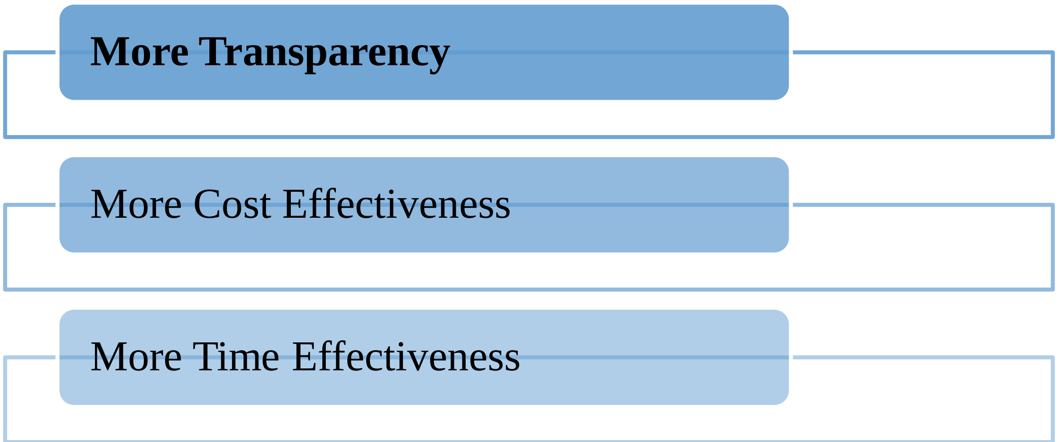

FIGURE 4. The Goals of the Project

The management team in THE DEPARTMENT wants to gain transparency in the overall process to make it more cost effective and reduce the lead-time. However, in this thesis the author will concentrate on the transparency of the project excluding in-depth analysis of the costs and lead-time. In the end, the author makes suggestions on how to improve the transparency in the repairing process. Additionally, the management team is responsible for the decision-making concerning implementation of the ideas.

1.4 Research Method and Data Collection

This research fulfills the criteria of two types of research: case study and action research. The aim of a case study is to examine one limited topic, for example a process. It tends to investigate, describe and explain the subject by asking “how” and “why” questions. Both qualitative and quantitave methods are suitable for a case study. The focus is to describe systematic and precisely the topic and analysis. (Saaranen-Kauppinen, Puusniekka 2006.) Secondly, the action research focuses on the practical problem solving. Both examiner and examinees have an active role in the research, which is based on a teamwork and cooperation. The aim is to achieve changes through the research. (Kuula 2006.)

This thesis is a case study about the Six Sigma project called Repairing Process Optimization. The first aim of the project is to describe the basic process flow as truthfully as possible. Secondly, after determining the process, the focus is on optimization and making improvements in it. Because of the types of the research determined above, the author decided to apply both qualitative and quantitative research methods.

A quantitative researcher examines numeric data by testing theories and hypotheses. Thus, the research proceeds from theory to hypotheses to conclusions. (Johnson, Christensen 2014, 18.) On the contrary, the aim of qualitative research is to make in-depth analysis about a certain topic. The quantity of the observations is usually smaller than in a quantitative research method. The research tends to answer to the following questions: what, where and when, likewise in a quantitative research, but additionally why and how. The aim is to understand profoundly the issues having an effect on the subject. (Hogan, Dolan, Donnelly 2009, 2-3.) The theory is used as background information in qualitative analysis but the results can differ from the theory. Analysis is made during the whole research. (Kinnunen 2014.) Qualitative and quantitative researches have different kinds of strengths and weaknesses. When mixing these approaches, the topic is researched from different points of view. Thus, the results are also more diverse than applying only one research method. (Johnson, Christensen 2014, 52-53.)

Because the author was working in the company during the internship, she was part of the project team. The other team members were aware that the author was writing a thesis about the project. The author collected information during the whole project between February and August in 2014. Information was collected through informal conversational interviews, discussions and team meetings. Firstly, the informal conversational interview is a spontaneously and loosely structured type of data collection (Johnson, Christensen 2014, 233.) Most of the conversations were very spontaneous and unscheduled during the project. Thus, recording them would not have been possible.

Secondly, the aim of the observations is to search for anything and everything that might be significant to the research question. As in informal conversational interviews, the method of data collection is field notes. The observer writes down notes during and after the observations. In order to ensure the authencity of the notes, a good way is to correct and edit them right after observations. (Johnson, Christensen 2014, 233, 238-239.) Observations are made in meetings and during conversations. The author makes notes in every discussion and meeting. The notes are corrected and edited with other team members or with the mentor of the author. Figure 5 below illustrates the data collection during the project.

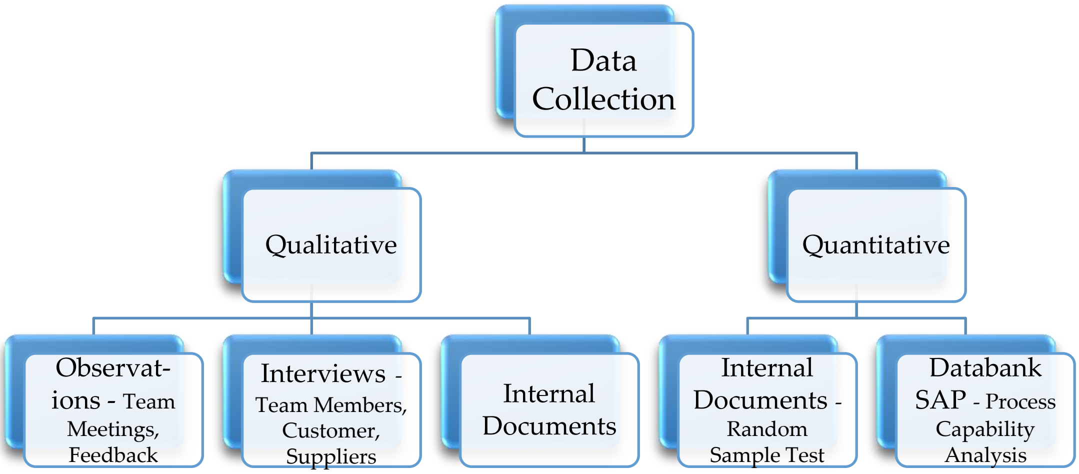

FIGURE 5. An Overview about the Data Collection.

In addition to the qualitative data, quantitative data is taken from SAP iPro system, which is a large logistical database used in the company. The analysis is made in excel and Minitab, which is a software for statistical analysis. Minitab is a registered trademark of Minitab, Inc (Minitab, Inc 2009). The author made a random sample test to analyse the data quality of repairing orders.

There are two ways to make conclusions about the data collected. Deductive analysis means that the research conclusions are made based on the theoretical framework. In inductive analysis the conclusions are led from the problems faced during the research. (Kinnunen 2014; Saaranen-Kauppinen, Puusniekka 2006). The case project is about process optimization that means that new points of view are needed in order to make improvements. Theoretical background is used as a fundament but the conclusions are based on the material collected during the project. Therefore, in this study the author will use inductive reasoning.

More information about the data collection methods, and how the author applies them will be discussed in chapter 4.2. Project Description and Implementation.

1.5 Structure of the Thesis

This thesis is divided in five main sections: introduction, theory chapters about logistics and Lean Six Sigma, the case section about Optimizing the Repairing Process in the production line and conclusions. In figure 6 below, the author presents the structure of the thesis.

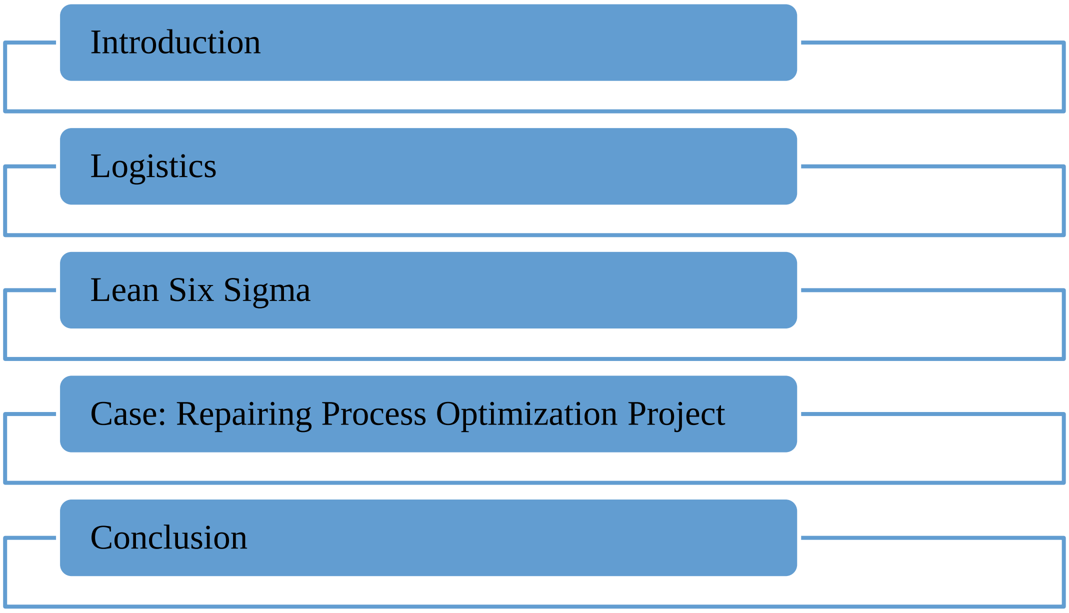

FIGURE 6. Structure of the Thesis.

In the introduction, the author presents the main topic of the thesis in order to give the idea to the readers, what the thesis is about, why the topic was chosen, and how the research and data collection were arranged.

Chapter 2 will give some very basic theory behind the logistics, supply chain, information management and information systems. The chapter will concentrate on information flow in the supply chain, and further discuss the information management and systems, which have a significant role in managing information in the supply chain. SAP is the major information system in the case company, and thus SAP software is introduced more in detail in this chapter.

The author will go deeper into the Lean Six Sigma method in chapter 3. The Six Sigma method is also used in the case company. This chaper will go through the theory behind the project steps that are used in the project Repairing Process Optimization as well. This chapter will clarify the project steps and the Six Sigma project toolbox for qualitative and quantitative analysis.

Chapter 4 consists of a short company description. The project depiction will present the project implementation, the research method and the data collection methods. The process description follows the five steps introduced in the theory chapter 3. The emphasis of the analysis will be on the information flow and transparency issues in information sharing and information systems. In the end of this chapter, the author will introduce the ideas for improvements and an implementation plan for them.

Finally, the author will conclude the results and findings, and evaluate the reliability and validity of the thesis and give some suggestions for future research. The final chapter will be a summary of the thesis.

2 LOGISTICS

This theory chapter will introduce some basic terminology and information about the logistics, supply chain, and how to manage them. In addition, the author will give further information about SAP, Systems, Applications and Products, which is a widely used software system. Lets first take a look to the theory behind logistics in general. Mangan, Lalwani and Butcher have chosen the following determination of the Chartered Institute of Logistics and Transport (CILT) in the UK for logistics in their book. Logistics is:

> *"-- getting, in the right way, the right product, in the right quantity and right quality, in the right place at the right time for the right customer at the right cost." (Mangan, Lalwani, Butcher 2008, 9.)*

This is a basic traditional way to define logistics. Nowadays, however, logistics and supply chain management are recognized as a vital factor in corporates' strategy. Not only the logistics is mapped in the standard software but also there is a growing demand for logistical experts. (Kappauf, Lauterbach, Koch 2012, 1.)

Kappauf, Lauterbach, Koch (2012, 4) see logistics from the management point of view. They have chosen the following definition to logistics according to American logistics society Council of Supply Chain Management Professional:

> *"Logistic management is that part of supply chain management that plans, implements, and controls the efficient, effective forward and reverse flow and storage goods, services, and related information – between the point of origin and the point of consumption in order to meet customers' requirements."*

In other words, the logistics has the key role in planning and controlling the material and information flow not only internal but also with external suppliers and customers. In the future, the emphasis will be on investing in IT solutions in order to manage the logistical planning and control over the processes. Contrary, costs will be reduced in operative logistics tasks by outsourcing for example transport, storage and packaging. (Kappauf, Lauterbach, Koch 2012, 3-4.)

Logistics planning, on the other hand, affects directly the quality of the service but also its costs. Inventory, vehicle routing and scheduling are common problems in logistics, and to manage these issues information systems are needed. (Conzales-Feliu, Semet, Routhier 2014, 200.) The following sub-chapters will go deeper to the supply chain, information management and information systems.

2.1 Supply Chain

There are three key flows in supply chain. There are physical flows of materials, flows of information and flows of resources such as finances, people and equipment. (Mangan, Lalwani, Butcher 2008, 150.) These three flows are moving between the company and suppliers. Mangan, Lalwani and Butcher define supply chain in the following way:

> *"The supply chain is the network of organisations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer." (Mangan, Lalwani, Butcher 2008, 10.)*

Supply chain management has a significant role in value creation, which is the key factor, when improving quality, decreasing lead-times and reducing costs. Internal developments are important in the starting point of the process optimization, but without external aspect it is impossible to achieve optimal process. (Fredendall, Hill 2001, 147.)

Federal and Hill have listed some key words on how to create a clear process with high quality partners:

- Vendor evaluating / certification programs
- Firms that are capable to deliver good quality, good lead-time and price
- Dependant on the power over supplier
- Possible to create a personal relationship (common improvement goals)
    1. Control plan: identify process flow, when out of control
    2. Personal visit: once a month
    3. Develop the trust necessary
    4. Common goals – improvements benefit both parties

(Fredendall, Hill 2001, 149-150.)

These activities are to deepen the relationship with external partners in order to develop the supply chain in general. Key supplier audits are one concrete example on how to make in-depth examination of the quality system and efficiently improve quality. However, they are quite expensive and time consuming since a team from the supplier and the customer companies are needed. (Fredendall, Hill 2001, 153.)

In conclusion, the supply chain is a network of organisations. Therefore, it is not enough that the company is able to manage the internal party of the supply chain. More importantly the supply chain is for connecting with partner companies and aims to create a mutual benefit. In the next sub-chapter, the author relates this topic to the information flow and transparency.

2.2 Information Management

As mentioned previously, logistics is about delivering products at the right time, in the right quality and quantity. Information flow and management have the key role in achieving these logistical goals. Transparency and information visibility are especially significant concepts that help to cope with the complexity. However, information visibility is not easy to obtain. Achieving transparency, integrated information systems and cooperation are needed between the parties such as suppliers and purchasers. (Mangan, Lalwani, Butcher 2008, 150.)

There might be some barriers when reaching transparency as well. The barriers can be cultural, financial, technical or organisational. It is important to identify these barriers in order to gain business benefit. Firstly, inequality between parties' capabilities and information security are examples of cultural barriers. Secondly, financial barriers may exist when there is a major difference in the size of the parties; for example a small-scale supplier and a multinational purchaser. In this case, it is unprofitable for the supplier to invest in an expensive information system. Thirdly, quite often parties do not use the same information systems, and this can cause technical barriers since the systems may be unable to communicate with each other. These problems are not only in hardware and software but also in agreements of sharing information. Finally, when implementing supply chain technologies, organisational barriers may occur. This is because of divergent processes, which should be aligning with the different levels of the supply chain. (Mangan, Lalwani, Butcher 2008, 151-152.) In other words, this means that the different processes in the supply chain are not connected and do not communicate with each other.

Sharing and integrating information is the key to better functioning supply chains. However, many businesses lack these abilities, and that causes problems in the material flows. Increasing the amount shared and integrated information have an effect on the visibility and transparency of the information in the company. (Goswami, Engel, Krcmar 2012, 277.)

Moreover, it is essential to understand how to use information effectively. Integration of the information flow is value-adding competences in a company. Sharing information allows the management team to see the opportunities of the supply chain. In other words, visible and integrated information helps to improve the logistical processes. (Goswami, Engel, Krcmar 2012, 278.) The next sub-chapter introduces information systems more in detailed.

2.3 Information Systems

A representative from a Finnish company Wärtsilä was interviewed in an article about the importance of information management, which has a significant role in a successful business. He emphasizes that using technology must bring value addition to the business and customers. There are local and global information systems. Wärtsilä uses one of the global software called SAP. (CIO &CFO 2012, 27-29.)

SAP is the world's biggest inter-enterprise software company founded in 1972 in Mannheim, Germany. It consists of the words Systems Application and Products. SAP aims to connect company database to wide range of applications. (Rouse 2009.) To give the idea about SAP, and what kinds of software solutions it provides, the author presents the lines of businesses below in figure 7.

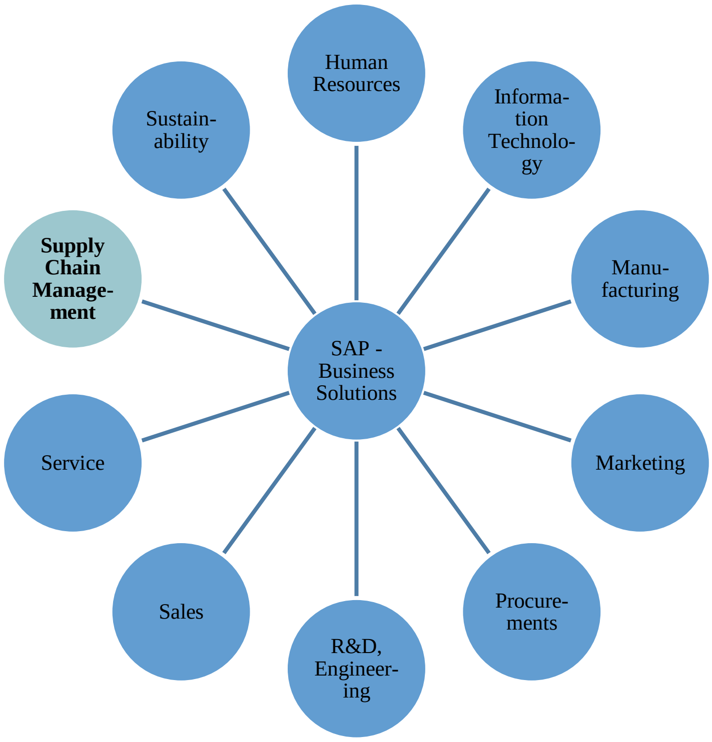

FIGURE 7. Lines of Business of the Company SAP. (SAP 2014)

There are many lines of businesses in SAP. Furthermore, they have a large amount of sub-categories. However, the author will not go deeper into all of them. Supply chain management and its sub-functions transport and warehouse management are more important to this thesis. Supply chain softwares have an important role in planning in general, planning the material requirements and company researches (Fredendall, Hill 2001, 47). The aim is to decrease inventory levels and improve customer service. Nonetheless, internal stock improvements are not profitable, if the improvements do not reach the whole supply chain. Supply chain management softwares are able to ease the communication between suppliers and customers. This requires allowing information sharing through the software between every member of the supply chain. (Fredendall & Hill 2001, 47.)

Lets take a closer look to the transport and warehouse management. The transport management involves always cooperation with external partners. The aim is to organize the exchange of commodities between the business partners. An appropriate software system, such as SAP, plays a significant role in achieving cost and time effectiveness. Service advantage and savings can be obtained by transport logistic and internal process optimization. (Kappauf, Lauterbach & Koch 2012, 11-13, 16.)

Warehousing is closely connected to the transportation. It includes the management of storage and maintenance of the goods. There are several warehouses in the logistic chain between raw materials and end customers. In addition, each of them has their own networks. The modern warehouse management systems are able to control and optimize complicated warehouse and distribution sevices. In addition, to the traditional management functions, such as quantity and location management, recent software systems give tools to control, plan and optimize the business strategies in the field of logistics. (Kappauf, Lauterbach, Koch 2012, 100-101.)

SAP distinguishes the functions of inventory and warehouse management. Basically, inventory management operates the stock regarding the quantity and value. Warehouse management controls the spatial divisions of the warehouse such as bin locations and processes within the warehouse. (Kappauf, Lauterbach, Koch 2012, 102.)

In conclusion, SAP is diverse software not only for logistics but also for the whole business from sales to human resource management. Now that the potential of logistics, supply chain and information management is introduced, it is time to go deeper in the theory behind optimizing processes. The next chaper 3 will be about the Six Sigma method, that is a tool to optimize processes such as a repairing process.

3 LEAN SIX SIGMA

This chapter presents the theory of the Lean Six Sigma project method, which is used as a project method in the case project Repairing Process Optimization.

3.1 Lean Production

Firstly, the author would like to introduce some background to the topic. Lean production has its roots in the car company Toyota and their Toyota Production Systems influenced by the car company Ford. The company wanted to achieve total quality in the processes by:

- Quick machine turnovers
- Elimination of waste
- Efficient production flows
- Low levels of inventory
- Faster total process time

This was how the method called just in time (JIT) was born. It aims to decrease the amount of stockpiling and inefficiency in processes. (Mangan, Lalwani, Butcher 2008, 39-41.)

3.2 Six Sigma

This chapter presents the five major phases in a Six Sigma project. They are illustrated in figure 8.

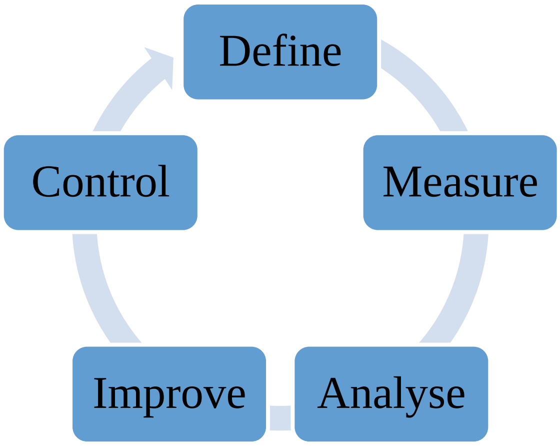

FIGURE 8. Six Sigma DMAIC Method (Kumar 2006, 1).

Firstly, the starting point of every effective Six Sigma project is to define the project focus, goals and specifications. Secondly, the process will be measured in order to find out, how well it meets the goals and specifications that were determined in the first phase. As a result of the measure phase, the relationship and the gaps between process output and customer expectations are recognized. This is also called process capability. (Kumar 2006, 1-8.) There are two ways to improve the process capability and quality. The process capability means, how well the process meets the customer specification. Firstly, variation can be decreased and secondly the process average can be changed closer to the target. (Windsor, S 2006, 1-3, 53.)

The next step is to analyse, how the process inputs and outputs are related to process variation. Analysis of variance (ANOVA), hypothesis testing and regression are examples of tools that can be applied to this analysis. Fourthly, the process inputs are changed in order to improve the process outputs. For example design of experiment (DOE) is often used during this step. Finally, the control plan ensures that the actions are made in order to achieve a permanent change in the process. (Windsor 2006, 5-6.) The five basic steps of the Six Sigma method consist of interphases. The following sub-chapters will give more in-depth information about each step.

3.2.1 Step 1 Define

Firstly, the project focus and goals must be defined. The second step is to determine the process steps. In the following figure 9, it is shown, how a process can be demonstrated.

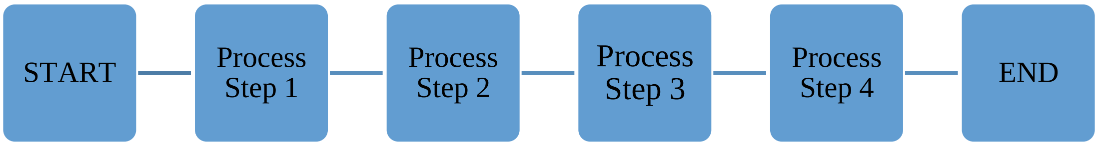

FIGURE 9. Process Mapping (Windsor 2006, 25).

The purpose is to identify process inputs and outputs. Process mapping is illustrated by using blocks connected to each other by lines. Every step has its own block. (Kumar 2006, 1-8.) One of the most difficult parts of Six Sigma is measuring the process performance. After determining the measures, the question is what kind of data should be collected. The aim is to find out how inputs affect the outputs determined in process mapping. (Windsor 2006, 35-36.) More about this topic will be discussed in the next sub-chapter.

3.2.2 Step 2 Measure

In Six Sigma projects, a crucial part of the project steps is to prove measurement systems. This step is called measurement system analysis (MSA). It is usual to rely on the measurement system without questioning it. The measurement system delivers data for decision-making, and that is why it is important to evaluate it. There should be no difference in the results depending on the evaluator. In other words, it has to be proved that the measurement is repeatable and reproducible despite the person. In Minitab software there are some statistical tools to evaluate repeatability and reproducibility (R&R). The selection of the tool depends on the data type. For attribute/discrete data there is the attribute gage R&R and for continuous measurement data the variable gage R&R. (Windsor 2006, 41-42.) Table 1 presents the data types and the units.

TABLE 1. Summary of Data Types (Windsor, S 2006, 53.)

Data Type	Units
Continuous	Dollars Time
Attribute	Pass/Fail Accept/Reject
Discrete	Errors per page Complaints per week

There are two categories for measurement errors: accuracy and precision.

- Accuracy shows the difference between the result of the measurement and the actual value (Mintab, Inc 2009).

- Precision indicates the variation that can be seen when the same object is repeatedly measured with the same device (Mintab, Inc 2009).

One or both of these errors can be in any measurement system. A device can be able to measure objects precisely, which means little variation in the measurements, but not accurately. One possibility is that a device is accurate but not precise. This means that the results of the measurement are close to the target value, but they have a large variance. The measurement can be both inaccurate and imprecise. (Mintab, Inc 2009)

After accomplishing previous steps, defining key process measures and proving the measurement system, the process capability can be analysed. In this analysis, the upper and lower specification levels are compared to the process. The specification limits normally indicate the customer expectations. Thus, the process capability analysis (PCA) shows, how well the current process correlates to the customer expectations. (Windsor 2006, 53.)

3.2.3 Step 3 Analyse

The aim of the analysis section is to research the relations of the inputs and the outputs. (Windsor 2006, 65.) There are several ways to make the analysis but the first step is to clarify the information and data with the quality tools:

- Graphs
- Pareto diagrams
- Control charts
- Cause-and-Effect Diagram

These tools are used to illustrate the important information of the project. Graphs are traditional tools to organize and summarize data simply and effectively. The reason for a usage of a specific graph must be clear. The difference between bar chart and Pareto is that Pareto arranges the greatest number from left to right. (Fredendall & Hill 2001, 64-68.)

Control charts, on the other hand, are special types of graphs. Normally, they illustrate the values as a graph, but also how the data moves. The goal is to show if the data is normal or abnormal. The most commonly used types of control charts are Xbar and Rbar, and they are always made together. Xbar illustrates the changes in the average value of the process. The Rbar clarifies the movements of variance. As in the process capability analysis, there is also upper control limit (UCL) and lower control limit (LCL). Additionally, there is the centre line (CL). When UCL or LCL is overrun there is something abnormal in the process and it is not under control. The points that vary inside the limits represent common variance. (Fredendall & Hill 2001, 66-68.) More about the control charts will be discussed in chapter 3.2.5. Control.

The Ishikawa cause-and-effect diagram, also known as fishbone diagram, is used to find out all the factors affecting the process. Common categories are materials, work methods, equipment, people, measure and environment. Normally, the diagram is made with the project team in order to find all the possible factors. (Fredendall, Hill 2001, 65, Holger, Weber &Wiendahl 2004, 104.) In figure 10 is presented the model for Ishikawa diagram.

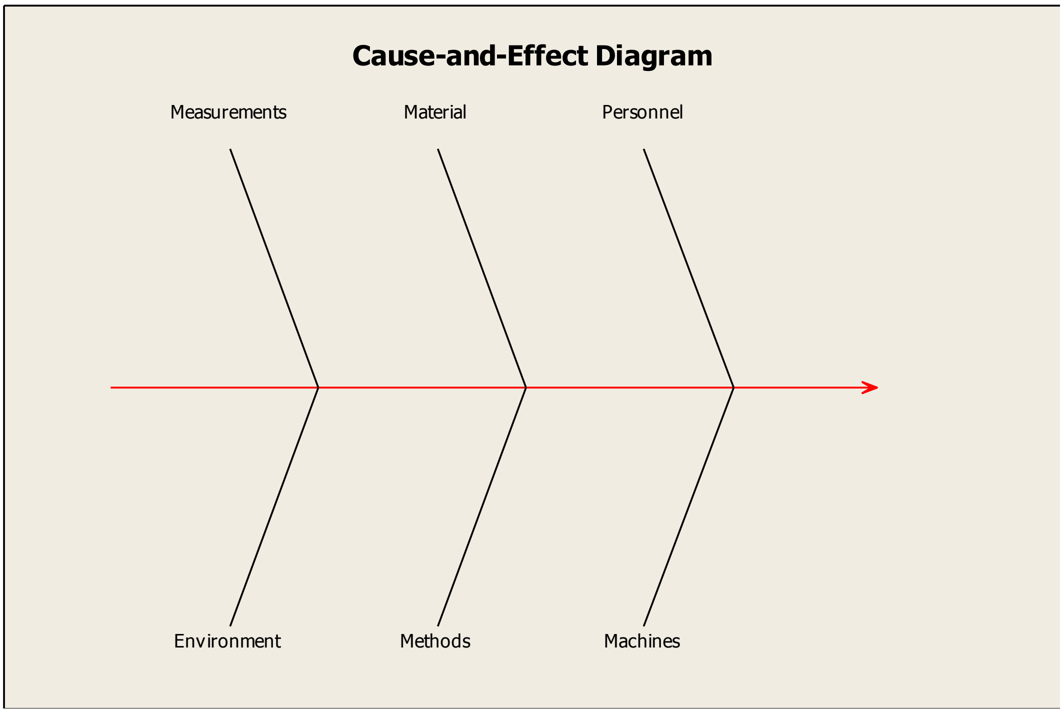

FIGURE 10. Ishikawa Diagram (Minitab, Inc 2009).

Hypothesis testing is one step forward in Six Sigma analysis. Hypothesis tests determine not only whether there is a relationship or difference between two units or not but also whether the relationship or difference is statistically significant. The null hypothesis means that there is no relationship or difference. The alternate hypothesis indicates that a relationship or difference exists. (Windsor 2006, 65-67.) Through statistical testing, it is possible to find out if the null hypothesis can be accepted or rejected. (Windsor 2006, 70, 101.)

3.2.4 Step 4 Improve

In the analysis section by applying hypothesis testing it has been determined, if there is a relationship or not. The aim of the improve section is to go deeper and define the relationship between the input variables and output variables (Windsor 2006, 103). Design of experiment (DOE) is the most used statistical tool.

> *"In a DOE we will expand on the relationship of the inputs to the output, Y=f(x) through the use of a series of designed experiments." (Windsor 2006, 103.)*

Design of experiments (DOE) is a tool to help to improve processes. The user is able to screen the factors to determine the important ones for explaining process variation. With Minitab statistical software, it is defined how factors interact and drive a process. In conclusion, the factor settings for an optimal process performance are found. (Minitab, Inc 2009)

Other suitable optimizing tool is regression. It can be used when both inputs and outputs are continuous. (Windsor 2006, 111.) With regression analysis it is possible to compare a response variable and one or more predictors. The aim is to define the relationship between them. (Minitab, Inc 2009.)

3.2.5 Step 5 Control

The last step is to summarize the results and make a plan on how to keep the process under control in the future. The control plan is a key tool to ensure that the changes are permanent before moving on to next problems (Windsor 2006, 113). The control plan contains the following steps:

List each step of the process.

1. Identify what is required to perform the process step (resources, computers, data etc.).
2. Determine the required characteristic(s) of the process step (amount/quality of information, time allotted etc.).
3. Determine the specification required of the characteristics (minimum/maximum time allotted and minimum/maximum requirements for next process step).
4. Determine frequency and sample size that will be used to verify that the requirement is met (once per day, 100% etc.).
5. Determine how the data will be monitored (control chart, automated controls etc.).
6. Determine what will be done when the controls are not met (reaction plan). (Windsor 2006, 113-114.)

The aim is to think of every step of the process, and how the input will be controlled. More importantly, the plan must include guidance, what is done when the input goes above the specification limits. (Windsor 2006, 114.)

As already mentioned in chapter 3.2.3, there are statistical tools to test if the process is under control or not. The control of the process is analysed before and after changes. Control chart is one way to control a process in long term. It is a visual method used to illustrate, how the process had been improved during the Six Sigma project. The aim is to bring the output inside specification limits and implement the methods in order to control its variation. (Windsor 2006, 118.)

In conclusion, the Six Sigma method is an overall description about a project flow. Step by step, the process is analysed and every phase brings information to the next project step. In the following chapter, the author will present the Six Sigma project Repairing Process Optimization in practice.

4 CASE: REPAIRING PROCESS OPTIMIZATION PROJECT

This chapter will be about the case study Repairing Process Optimization in Company X. It will introduce the case project and the repairing process. The project steps will follow the Six Sigma project steps presented in the previous chapter.

4.1 Project Description and Implementation

The author would like to present the project before going more in-depth analysis of the process. The manager of the department above department A gave the order for the project called Repairing Process Optimization. The need for the project was a result of the previous project Inventory Levels Optimization. The project character document (Appendix 1) was the starting point for Optimizing the Repairing Process project.

In chapter 3, the author presented the theory behind the Lean Six Sigma. In the theory chapter 3, the five basic project steps of Six Sigma were introduced. They are define, measure, analyse, improve and control. In addition to these five steps, the company has determined 15 interphases for the project. Figure 11 below shows the basic steps but also the sub-sections of the project. The task of the author was to learn the insight of the steps with the help of her mentor during her internship. It is a company policy to document the findings in team Power Point presentation and Excel to-do-list. The author was responsible of the documentation of the project.

- DEFINE
  - 1. Project Character
  - 2. Voice of the Customer
  - 3. Process Flow
  - 4. Potential
- MEASURE
  - 5. Measurement System Analyse (Y)
  - 6. Process Capability Analysis
- ANALYSE
  - 7. Determine possible Xe
  - 8. Analyse the Xe
  - 9. Dependencies
  - 10. Functional Coherence Y = f(x)
- IMPROVE
  - 11. Optimized Configuration of the Xe
  - 12. Determination of the Tolerance
  - 13. Process Capability of the Y and Xe
- CONTROL
  - 14. Control Plan
  - 15. The End of the Project

FIGURE 11. Process Steps in Company X. (Company X, 2014)

Firstly, the project character defines, who is the customer, what is the basic process flow and what is the potential of the project. This is the important step to get known to the process more detailed. The author began to collect material by reading documents in February 2014. This helped the author to get known and understand the process flow. This was essential so that the author was able to ask the right questions later in the project. In March, the author had the main conversational interviews about the process flow with the SAP experts, the warehouse keeper and the customer from the product line. Through these discussions the author began not only to perceive the process flow in more detail but also the steps that could be improved.

A significant Six Sigma tool used in the case company is SIPOC (Supplier, Input, Output, Customer). The tool will be explained more detailed later in the following sub-chapters. SIPOC was used as a fundament in every interview and team meeting. The discussions and informal interviews were documented by note making. These notes were transferred in a SIPOC table and an Ishikawa Diagram. Ishikawa cause and effect diagram was introduced in the theory chapter 3. Since the project is relatively small, clarifying questions could be asked through the project by phone calls, e-mails and face-to-face conversations.

Secondly, the process needs to be measurable. In this process, there is no metric instruments used; therefore the author tested the quality of the data in 40 repairing offers and SAP iPro information system as a random sample test. In the capability analysis, the author analysed the repairing orders from three months before the project start. These analyses were made with Minitab program, which is practical software for applying statistical analysis such as distribution analysis and capability analysis. More about these will be discussed later in the following sub-chapters.

Thirdly, the effecting factors (Xe) on the project units (Y) must be determined and analysed. The author collected them in the Ishikawa diagram during the discussions and team meetings. After this, all the factors were analysed by using Cause and Effect Matrix (C&E). In C&E, the factors are prioritized in order to determine, which factors have the biggest effect on the process. After the process step 8, it started to be more difficult to literally follow the Six Sigma project flow determined previously in this chapter in the figure 11. At this point, the project turned to be more qualitative and less quantitative, and applying statistical tools in Minitab turned to be less reasonable. This is why the author concentrated on describing the dependencies between the project units (Y) and factors (Xe).

Fourthly, the aim is to find the steps that need to be improved based on the analysis. As stated earlier, in this case the statistical analyses are less reasonable. The step number 11 is therefore about presenting the possible improvements. The step 12 is to determine, how much the changes would cost. Finally, number 13 is to determine the changes in the process capability after the improvements.

Finally, there is a need for a control plan before the project end. The control plan is made to ensure that the improvements are made as planned. The author will present a control plan from the transparency point of view in the following sub-chapters. As stated in the limitations to this thesis, other points of views are excluded.

In the following figure 12, it is summarized, in which time period the author was collecting the material for the project and for this thesis.

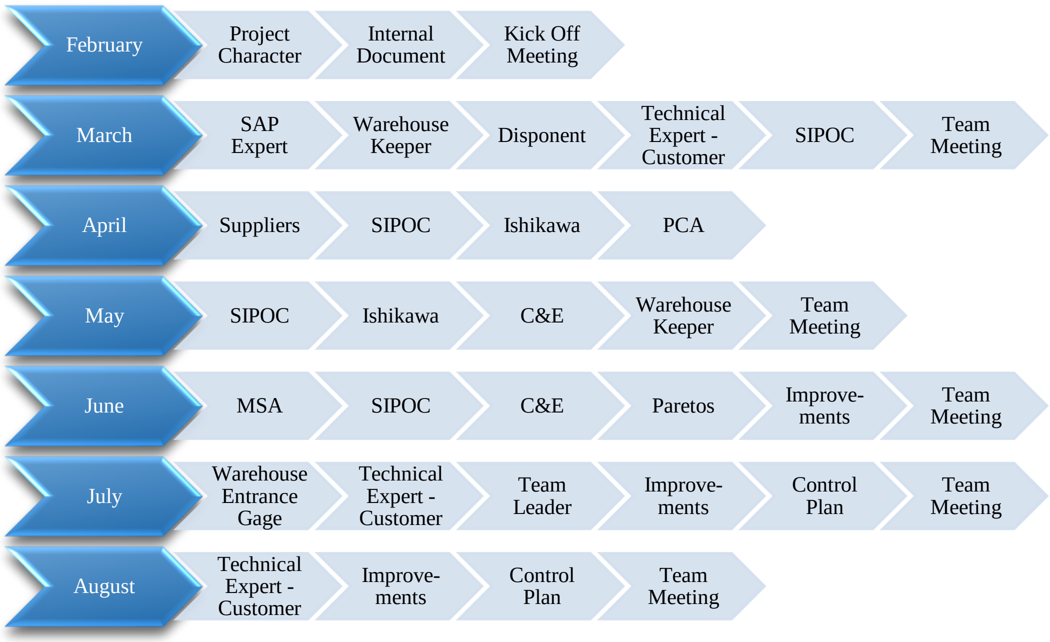

FIGURE 12. Timeline of the Observations.

The project start was on 15.02.2014 is stated in the project character (Appendix 1). Since February the author has been collecting material for the project and for this thesis. The project end will be in November 2014, and thus for instance control plan is still on making, and decisions about the improvements are made after this thesis. In the next sub-chapters, the author will go deeper to the project and repairing process by following the five main project steps introduced in the theory chapter 3.

4.2 Define

Step 1. Project Character

The project started with the project character (appendix 1), which is an official order for the project. The timeline for the project, the project team, descriptions, the aims and the method of the project are stated in the document. The Six Sigma method is commonly used method in the company, and thus it is the method for Optimizing the Repairing Process.

The project units (Y) and the customer specification limits are defined in the project character. In this project, there are two units:

Y: Repairing costs < 1,8 €

Y1: Lead-time < 40 Days

The project advance knowledge about project goals and limitations, and the responsibilities are stated in the project character. During this phase, the author's task was to make the schedule for the project. The schedule is found in appendix 2.

Step 2. Voice of the Customer

The step number two is to determine the customer's needs. As stated earlier, the customer of the project is the management team. For the management team the main aim is to make the process more cost-effective. Customers of this process are the people in the production line, who bring parts to the stock. For them for instance long lead-times and lack of information about the defects cause customer dissatisfaction. Both needs must be taken in consideration.

The Voice of the Customer (VoC) is a tool to define the customer need. It determines the facors that are critical to satisfaction. These factors are devided in three parts critical to quality, critical to costs and critical to delivery. In the following figure 13, the author has summarized the customer needs.

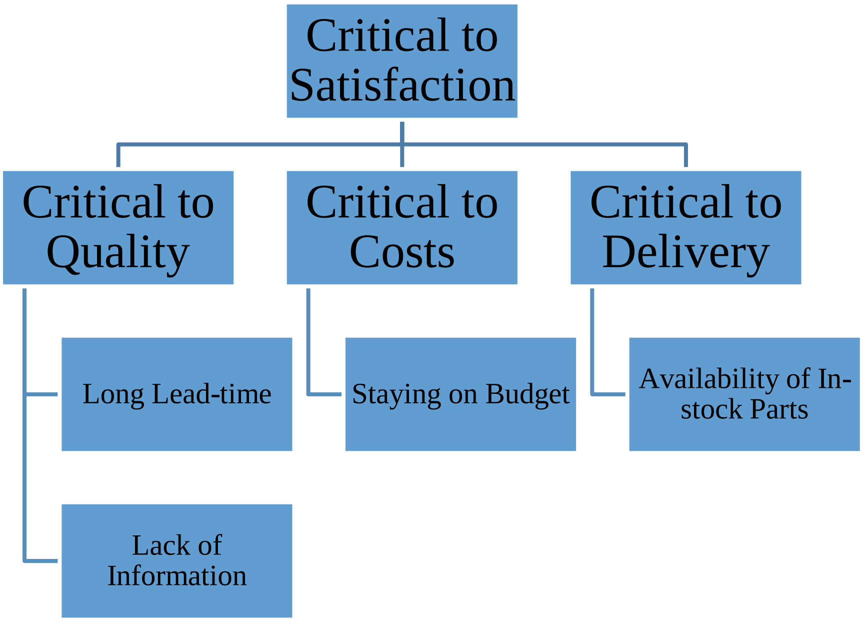

FIGURE 13. The Voice of the Customer

There are two factors that are critical to quality. Firstly, long lead-time is a risk for the production of end commodities. Secondly, lack of information or problems in the information flow are risks for the decision-making. Staying on budget is critical to costs, and that is especially critical to the satisfaction of the management team. Finally, availability of the in-stock parts is critical to the delivery, which is a vital element to the satisfaction of the production line. The customer needs were agreed in the team. (Team Meeting 3 2014.)

Step 3. Process Flow

During the third step the actual process flow is determined. First, lets take a look to the ideal process flow shown in figure 14. The optimal process flow is already known before the project start.

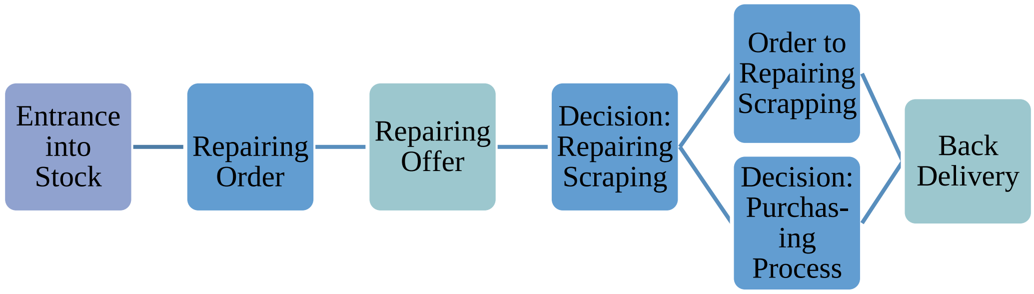

FIGURE 14. Process flow – Repairing Process in Company X. (Company X)

The ideal process consists of five basic steps. Firstly, the customer brings a part to the stock. Secondly, the warehouse keeper takes the part. Then, he creates the repairing order in the database SAP iPro and contacts an external supplier. Internal transportation transfers the part to the logistic centre, where the part is packed in a parcel or on the pallet depending on the type of the part. The part is transferred to the supplier who investigates the need for repairing. The supplier sends a repairing offer that includes information about the costs of repairing. Based on this document, the warehouse keeper makes the decision whether the part is profitable to repair or scrap. After this decision, the part is repaired or scrapped by the supplier. The repaired part comes back first to the logistic centre, from where the internal transportation brings it finally back to the stock. (Company X 2014)

In the internal documents, the spare parts are devided into two types. There are in-stock and not-in-stock parts. In the following table 2, the author has collected a few examples of the in-stock and the not-in-stock parts to give an idea about the differences between them.

TABLE 2. In-stock and Not-in-stock Parts.

In-stock Parts	**Not-in-stock Parts**
Angle Bolt	Measuring Instrument
Engine	Tyre Validator
Vechicle Control	Cordless drill
Vacuum Pump	Borer
Controler	Vacuum Cleaner

In-stock spare parts are important parts of the machines in the production line. Not-in-stock parts are mainly hand tools and not essential to the production of the end goods. (Company X 2014) The process flow depends on whether the part is in-stock or not-in-stock part. If the part is in stock the customer from the product line is able to get a new spare part right away, when the defected spare part enters the repairing process. On the other hand, the customer needs to wait for the not-in-stock parts from the repairing process since for them there are no spare parts in the warehouse. (SAP Specialist Planing 2014.)

By conversational interviewing in the project team, the author focuses on determining the problems in the process flow. The SIPOC is an effective tool to go deeper to the process (Appendix 3). In SIPOC each process step has a supplier, input, output and a customer. Now, let’s take a closer look to the process flow determined in SIPOC.

Firstly, the employee of the production line brings the part in the NMP warehouse for non-productive material. In the cases, when the part is not-in-stock spare part, the manual repairing order has to be filled. Furthermore, stock spare parts are systematic in SAP iPro database with a material number. The error notification appears in the system before the part enters the repairing process. The disturbance can be for instance in a motor of a robot. Contrary, not-in-stock parts are not systematic in the database, which is why there are no error messages in the system. An example of a not-in-stock part is a vacuum cleaner. The warehouse keeper gives the not-in-stock parts an individual disposable material number everytime they enter the repairing process. Additionally, in-stock parts are ordered only when the inventory level goes under the limit, whereas a not-in-stock part needs to be ordered every time it is scrapped. (SAP Specialist Planing 2014)

Secondly, the stock keeper investigates the documents and puts the order in SAP. The new price of the part should be over 400 € so that the repairing of the part is profitable. This is the company policy. The warehouse keeper is in contact with the external supplier and prints the documents needed for the transportation. (Warehouse Keeper 1 & SAP Specialist Planing 2014). Thirdly, the internal transportation will pick up the part to the logistic centre. In the logistic centre, the employees pack the parts on pallets or in packages depending on their weight. From the logistic centre the parts leave normally during the same day. (Logistic Centre Employee 2014.)

Fourthly, the external supplier investigates the part and sends a repairing offer. The cost of the repairing, and how much would a new part cost, should be the stated in the repairing offer. Another company policy is that the repairing price should not be more that 60 % of the new price. However, there are exceptions to this policy; for example parts that cannot be ordered anymore. Based on the offer, the stock keeper makes the decision whether the part will be repaired or scrapped and informs the supplier. (Warehouse Keeper 1 & SAP Specialist Planing 2014).

If the part is going to be repaired, a stock keeper makes a document called BANF. In the document, there are the repairing price and the new price of the part. The management team uses this document as a basement for the decicion-making for the cost approval. When repairing is allowed the warehouse keeper sends the order to repairing called BEST to the supplier. Figure 15 shows the relation between the documents.

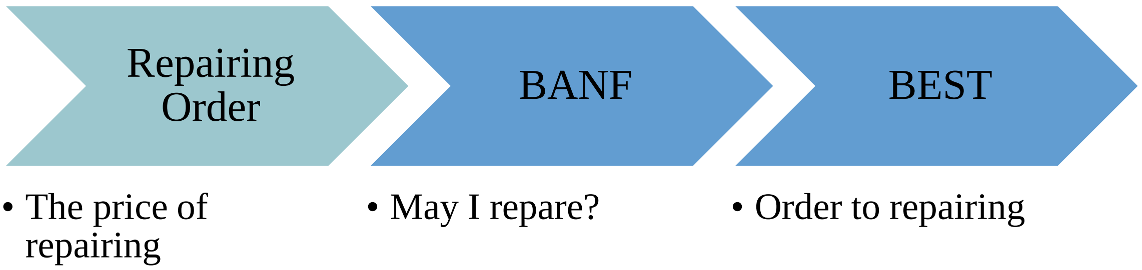

FIGURE 15. Document flow of the Repairing Process.

After the repairing, the external company sends the part back to the logistic centre, from where the internal transportation transfers it to the warehouse. The part will be given back to the customer in the production line or it is stored. (Warehouse Keeper 1 & SAP Specialist Planing 2014).

If the product is scrapped, there is one part less that before. Disponent is the person responsible for the order of the new spare parts. He orders a new spare part, if the inventory alarm in SAP tells that the amount of the spare part is under the limits. If the part is not-in-stock product, the disponent orders a new product when the defected part is scrapped. However, this is the purchasing process, which is not discussed in-depth in this thesis.

Step 4. Potential

Finally, in the fourth step of the define phase, the potential of the project is stated. The author stated the potential in a following way:

- Cost reduction
- Controlled process inside the specification limits
- Increasing transparency and sustainability of the general process

In conclusion, these four first steps are made simultaneously and SIPOC is under improvements through the whole project. Each discussion, project meeting and casual interview brings more accurate information about the process, and especially about the parts of the process, which need to be developed.

4.3 Measure

Step 5. Measurement System Analysis

The fifth step is called measurement system analysis. Because of the abstract nature of the project there are not real measurement systems in this project. Consequently, the author went through 40 repairing offers to inspect the data quality regarding the project units costs and lead-time (Appendix 4). Data quality is a significant part of the transparency.

In the random sample test regarding the data quality, the author compared the costs in repairing orders to the costs stated in SAP. Additionally, the author tested whether the cost of the repairing is 60% of the new price. She found out that the actual new price was not always in SAP. However, only few unclear repairing orders were found and all of them were possible to clear with the stock keeper. The result of this random sample test was that data quality concerning repairing orders is 100%. (Warehouse Keeper 2 2014.)

Step 6. Process Capability Analysis

Process capability analyses are made in the sixth process step. It was agreed in the team that the analyses are made with the data three months before the project start (Team Meeting 3 2014). Before moving on to this analysis, lets recap the project units (Y) stated earlier in this chapter.

- Y: The repairing price stated in the repairing order. It is measured by euros (€).

- Y1: The lead-time of the process. It is measured by days (d). Lead-time: Arrival in the warehouse – Transportation to supplier – Return in the warehouse – Back to the customer in the production line.

Firstly, the author took the repairing orders from the database SAP and with the Microsoft Excel transfered them in a suitable form for Minitab. During the first analysis it was discovered that there are lots of extreme cases. Because only the normal process is wanted to be researched, in the project team was agreed that lead-time less that a day and more than 120 days were taken out (Team Meeting 3 2014). Repairing cases that take only a day are located on the factory and they do not go through all the process steps. Calibration is an example of repairing that takes less than a day. The cases over 120 days are extreme situations that do not describe the normal repairing process. (Team Meeting 3 2014.)

In the statistical software Minitab, the process capability of Y costs and Y1 lead-time were inspected. The following to figures 16 and 17 will show the capability of the both units.

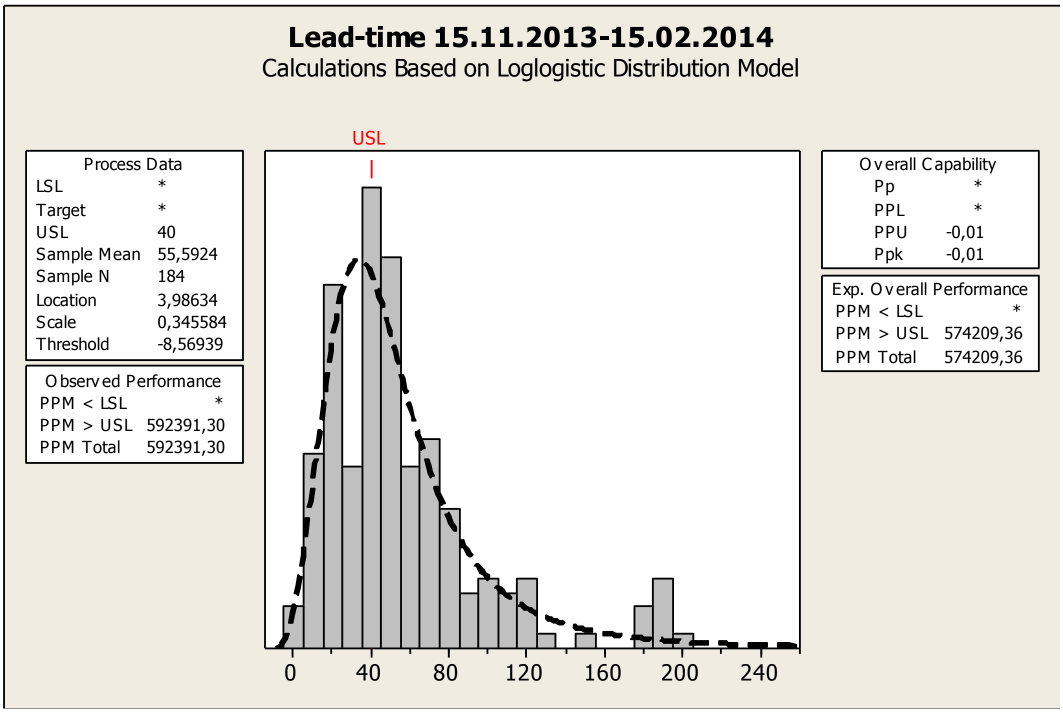

FIGURE 16. The Process Capability of the Y1 Lead-time**.**

Figure 16 illustrates the capability of the process lead-time. After distribution analysis, the author found out that the process is not normally distriputed and the best match was loglogistic distribution. The loglogistic distribution means that the logarithm of the variable is logistically distributed. Logistical distribution is similar to normal distribution but it has longer tails. (Minitab, Inc 2009)

The upper specification limit (USL) is 40 days, which is a customer specification limit stated in the project character (Appendix 1). As it is seen in the figure, the process violates the USL even though the extreme cases, lead-time over 120 days were taken out. The sample mean is about 38 days, which is inside the limits. Parts per million, PPM rate is 369 749, 75. PPM tells the number of parts per million above the upper specification limit. (Minitab, Inc 2009) In other words, approximately 37% of the reparartion orders take longer than 40 days.

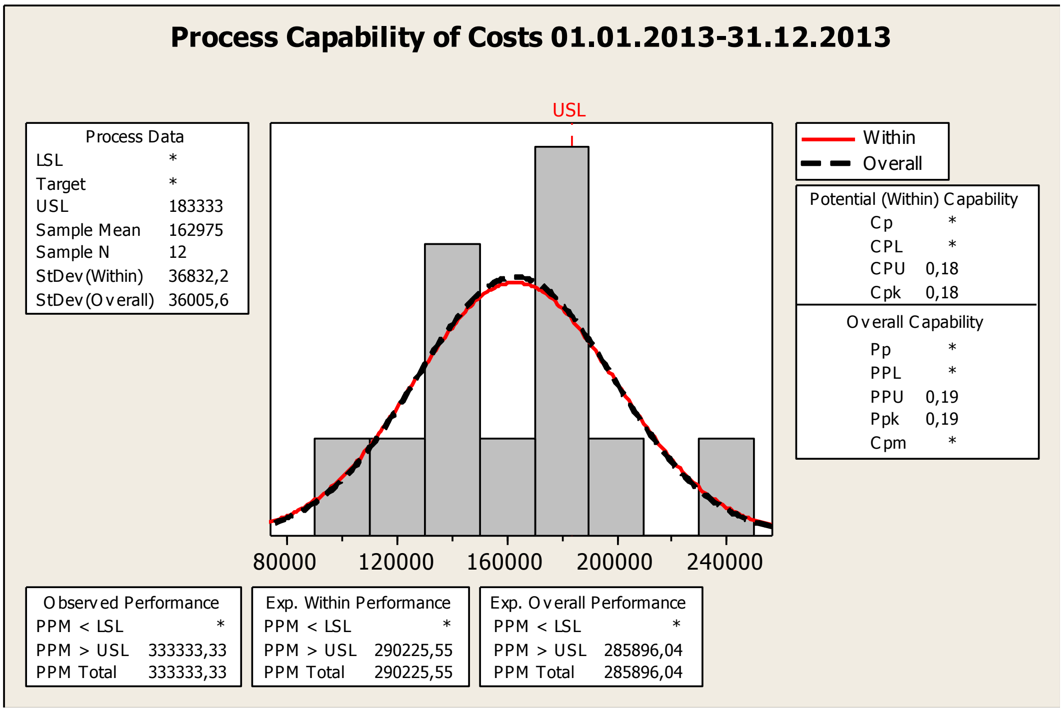

FIGURE 17. The Process Capability of the Y Costs

Figure 17 above demonstrates the capability of the costs between 01.01.2013-30.12.2013. The reason for the different period of time is that the costs are per month in the figure. There would only be three samples in the figure, if the time frame were the same as for the lead-time. Three samples would not tell about the process and how well it meets the customer specification limits.

The upper specification limit was calculated by dividing the goal of the year 1,8 M€ by 12 months. As it is seen in the figure, the upper specification limit is violated. The sample mean per month is 167 380 € during 2013. In this case, the PPM rate is 285896, 04, which means the number of parts per million above the upper specification limit. In other words, 29% of the repairing orders are over the specification limits.

In this thesis, the primary focus is in qualitative research, which is why the author does not go deeper in the capability analysis. However, after these two steps the units and the whole process is better known; both costs and lead-time are over the specification limits. The reguirement to the analysis is to understand the process. The next aim is to determine factors having an effect on costs and lead-time and the dependencies between the factors (Xe) and the project units (Y).

4.4 Analyse

Step 7. Determine Possible Xe

The aim of the seventh step is to collect all the factors (Xe) having an effect on the process. The author determines the possible factors in the Ishikawa diagram. The Ishikawa was already introduced in chapter 3. In Company X, there are six sections in the diagram: method, people, machine, measurement, environment and material.

The author began to gather material about the factors already during the first project phase define. The original Ishikawa diagram is found in appendix 5. In addition, the author made a figure 18 about the information in Ishikawa diagram.

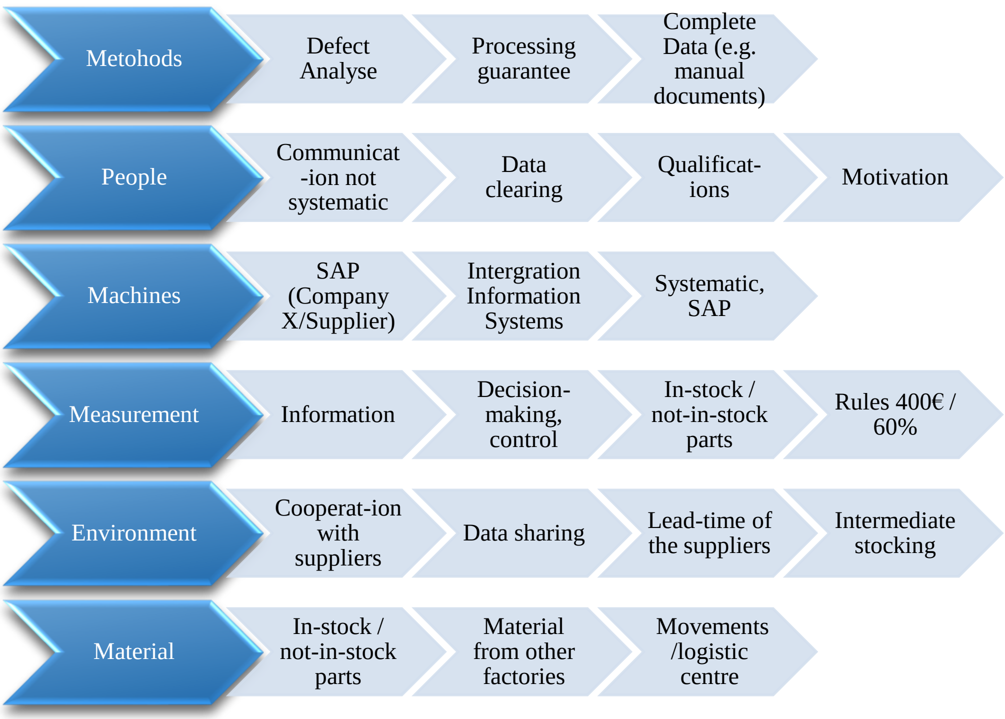

FIGURE 18. Ishikawa Diagram.

Firstly, lack of error analysis and lack of information sharing have an effect on the process flow. The error analysis from the maintenance employees, do not reach the suppliers (Warehouse keeper 1 2014). The error notification is in SAP iPro, but it is in other working field that is not connected to SAP field for repairing (Team Meeting 5 2014).

Secondly, automated and systematic communication and data clearing are people related factors. Accroding to the warehouse keeper, data clearing is necessary especially when a part is not-in-stock part and the documents are made by hand (Warehouse keeper 1 2014). In addition, employees' qualifications and motivation have an effect on the quality of each process step. For instance, it affects whether all the information is asked and given during each step to quarantee an efficiently progressing process. Qualifications mean that the people have sufficient educations and/or orientation to the work assignment.

Thirdly, the connections between different information systems have an effect on the process. The connections can be internal or between the company and supplier. During the measurement analysis, the author familiarized with the quantitative data. She found out that the SAP is not used as effectively as it could be. For instance, serial number is the only way to track the frequency of the repairing but it is not always in the system. Additionally, the new price of a product is not always easily available.

Fourthly, the information does not always reach the management team about how the costs of spare parts are divided between departments. This has an effect on transparency of the decision-making process whether the spare part should be repaired or not. (Team Meeting 4 2014.) Furthermore, there are two requirements for the repairing process that are mentioned earlier in chapter 4.4. The new price of the part should be over 400€ so that the part can enter the repairing process. In addition, the repairing price should not go over 60% of the new price. It is not transparent whether the spare parts, which new price is under 400€, are systematic scrapped or not. The reasons, why the repairing price should be under 60%, were unclear as well. (Disponent, SAP Specialist Planning 2014.)

The environmental factors are related to suppliers. As stated in chapter 2, the external factors have an important role in optimizing a supply chain. However, the possibilities to affect the external factors are limited. At the moment there is no systematic information sharing for instance about the defect analysis. The suppliers do not receive suffiecient defect descriptions from the production line and they do not forward their analysis to the maintenance employees (Technical Expert 2014). The lead-time outside the company is less transparent. Sometimes it is longer because of intermediate stocking by the transportation companies (Feedback Round 2 2014).

Finally, as mentioned earlier in the beginning of the process description, the non-productive material is divided to in-stock and not-in-stock parts. The processes of the in-stock parts and the not-in-stock parts differ from each other. This has an effect on the process. In addition, the logistic centre has a vital role to the lead-time if the part is not sent as soon as possible. More about all these factors will be discussed later in this analysis section. The aim of the next step is to aggregate and prioritize the factors by using Cause and effect matrix, C&E.

Step 8. Analyse Xe

C&E (Appendix 6) ranks the effecting factors in a sense of, how a significant effect they have on the lead-time, costs, availability and transparency. Figure 19 summarizes the C&E. In the figure, it is shown the priority of the factors (Xe) having an effect on the process units (Y).

1. Data Quality in SAP iPro
2. Control/Reporting: Costs
3. Control: Defect Analysis, Lead-time
4. Warehouse Movements, Frequency
5. Data Quality: Documents
6. External Lead-time
7. Inventory Levels
8. In-stock / Not-in-stock

FIGURE 19. Summary Cause and Effect Matrix.

Firstly, the author summarized all the factors showed in Ishikawa into eight themes and made a suggestion about the ranking. Secondly, the valuation was agreed together with the project team members who have deeper professional knowledge about the process. As a result, the most significant factor is the inefficient usage of SAP iPro. The next two most crucial factors are both related to control and reporting. There is less reporting about the costs per department, although it would bring transparency in the process. Furthermore, there is no defect analysis forwarded for the different parties of the process. (Team Meeting 4 2014.)

In the fourth rank are warehouse movements and frequence. In other words, how the spare parts move during the process and how often they are sent to the external suppliers? Data clearing is the next significant factor and it is also related to data quality. The aim is that the process is direct from the start until the end. This means that no rework or data clearing is needed and the process goes forward as in the ideal process flow was described previously in the sub-chapter 4.4. However, as mentioned earlier, the process is divided in two processes instead of one clear process flow. The actual process flow differs from the ideal process flow depending on whether the part is in stock or not in stock. Moreover, the lead-time of the supplier has a huge effect on the total lead-time. Nonetheless, the ability to influence to this external part of the supply chain is more difficult that affecting the internal supply chain. (Team Meeting 4 2014.)

Step 9. Dependencies

After ranking the most important factors having an effect on the process, deeper analysis about the dependencies are needed. The ninth step is about investigating possible dependencies between Xe and Y costs and Y1 lead-time. As mentioned earlier, there is less benefit of using statistical tools, which were introduced in chapter 3. Therefore, the author will describe the issues related to transparency.

Let’s take a closer look to the transparency from the information sharing and data quality points of view. Firstly, overall there is no systematic information sharing between the departments. No reporting and analysis about the costs per department is done. Moreover, the management team makes the final decision about the repairing. However, they are not technical experts and they lack the knowledge about the relation between repairing price and technology. (Feedback Round 2 2014). This has a negative effect on the decision-making since not all the information is available. Secondly, the process lacks of internal and external information sharing about the defects. In every feedback meeting with the customers from the production line stand out the need for the defects. Because of the lack of information, technical experts cannot do analysis about them. (Feedback Round 1,2 & 3 2014.)

Thirdly, as mentioned before, it is not transparent whether the parts, which new price is under 400 €, are systematic scrapped. Additionally, the reasons for the rule 60% of the new price are not transparent. Consequently, nobody can say if the 60% of the new price should be left as it is or for instance rose to 70% in order to achieve cost-effectiveness. (Disponent, SAP Specialist Planning, 2014)

Finally, the technical experts do not get any information about the movements of the spare parts. Information is not shared when the part is sent to the supplier or when it comes back. Thus, the experts do not know about the delay. Furthermore, there are cases when the logistic centre is hesitating with the transportation of the parts. This can occur for instance if they are waiting for a less expensive transportation. Other problem related to the lead-time is intermediate stocking by the external transportation stock. This can happen, when the supplier is far a way and the transportation company collects deliveries together in their own warehouses. All in all, the technical experts would also like to have information about the certain movements of the parts. For example when the part leaves the company and when it is sent back to the stock. (Feedback Round 2 2014.)

Technical experts are not satisfied to the data quality of SAP either. Basically, there is no way to see for instance if the spare part or the same technology is repaired every month. Technical experts would like to have a notification from SAP if the part is already repaired. Other idea was that through the paper flow and documents could be possible to tell if it is profitable to repair a part twise. For his kind of tracking also the defect analysis are needed. (Feedback Round 2 2014)

The next sub-chapter will introduce some improvement ideas to these problems.

4.5 Improve

Firstly, in this project adapting the Six Sigma tools in Minitab was less reasonable while the material collected is mostly qualitative. This is why, the author concentrated on describing the problems and ideas. Secondly, as seen in the schedule of the project (Appendix 2), the project will continue until the end of this year. Thus, for instance the implementation of the control plan will be agreed with the department manager in the end of the project. Because of these two reasons the final two steps differ from the steps illustrated previously in the theory chapter 3 and in the beginning of the case study. The last steps are made simultaneously. According to the research question of the thesis, the author will concentrate on creating ideas for information visibility and transparency. As mentioned in chapter 2, shared and integrated information has a leading role when planning improvements.

This part of the thesis is divided into two sections: internal and external improvement ideas. Table 4 summarized the improvement ideas.

TABLE 3. Internal and External Improvements.

Internal – Team	**Internal – Plant**	**External**
Two Processes → One Process	Cooperation – Information Sharing	Transparency – Lead-time
SAP Data Quality - Serial Number - New Price - Defect Codes - Quarantee - Search factors	Qualifications - Cost Approval - Exchange → Second Hand Part	Cooperation – Information Sharing - Electronical Analysis - Mutual Number
SAP Notifications - Frequency - Certain Movements	Cost & Volume Analysis - Specification Limits	Cost Approval - Quartal Commission
Connections between transactions		

The internal problems have two dimensions; there are issues that can be improved intern in the team and there are problems to solve concerning the whole plant. Conversely, in the section about external improvements the author introduces the ideas for developing cooperation with the suppliers. As stated in the limitations of this thesis it is the team leader’s task to make the decision whether investments to these improvements will bring value addition to the department and to the process.

Internal improvements

The internal improvements are divided into internal issues intern in the team and internal improvement potential in the whole plant. Lets take first look at the issues that need to be improved in the team.

Firstly, there should be one clear process, but already in the beginning it is divided into two different processes. There are three major differences between the repairing process of the in-stock and the not-in-stock parts. Firstly, the in-stock parts are more transparent through more systematic documentation. The in-stock spare parts are in SAP iPro database before entering the warehouse and before the actual start of the repairing process since the error message is directly connected to the system. When the defect occurs the error message appears in the system and the employees from the product line need to take the defected part to the warehouse. The warehouse keeper puts the not-in-stock parts into the system only when the manual repairing documents in the beginning of the process are filled. Furthermore, the products that are not in the stock do not have any error message and the reasons for them entering the repairing process are not always as transparent as they could be.

Secondly, the in-stock parts have their individual material number and with this number they can be found in the warehouse. The not-in-stock parts, on the other hand, do not have systematic number system. They are given a disposable repairing number every time they enter the process. However, the number is never the same for a same spare part and the frequencies of the not-in-stock parts is impossible to track. Finally, repairing documents depend on the type of the spare part. As the warehouse keeper is able to get the document for the in-stock parts directly from SAP, for the not-in-stock parts the employees have to write a manual document about the defects and reasons. Nonetheless, that is not their main task and the descriptions of the errors are most of the time insufficient. This causes data clearing as mentioned before in the analysis. To make the repairing process more clear these two processes should be standardized. It might not be possible to make them completely similar but there is potential to organize the not-in-stock parts in a more systematic way.

Secondly, at the beginning of the project, it was found out that the SAP database is not used as productively as it could be. One point is the separation of these two processes described above, but more importantly some of the fields are used ineffectively. In general, there are empty fields that could bring more transparency and control over the process when these fields were used properly. Firstly, serial number is used when it is easily found. However, serial number is the only way to track the frequency. Secondly, quarantee time and defect codes do not exist in the system at all. Thirdly, when somebody needs information about the defect analysis, he needs to open the individual repairing order to discover the long text describing it. Fourthly, the new price of the spare parts is not always easily available. Finally, to be able to analyse the technology and bring more consciousness about the costs, new search factors for SAP iPro is needed. (Team Meeting 6 2014.)

Thirdly, there is a need for SAP notifications about certain movements and frequencies. The notifications are already possible for every movement of the spare part. However, this would cause too many useless emails for the technical experts. Now it should be clarified, if it was possible only for certain movements. (Feedback Round 2 2014.)

Finally, for example the error message does not reach the warehouse keeper since different kinds of transactions are used in the production line and in the warehouse. It should be investigated if the connections between different transactions could be connected. (Feedback Round 2 2014.) The team is responsible for the improvements in SAP and it is their task to analyse which improvements bring value to the parties of the repairing process.

As shown in table 4, there are also some improvement ideas for the whole plant between the departments. Firstly, there is lots of space in general to improve the cooperation and information sharing between different departments. A lot of information is available but it is not integrated in SAP and nobody has been using it for analysis. However, the production line is willing to deepen cooperation in order to achieve more transparency to frequencies and costs of the repairing. (Feedback Round 3 2014.)

Secondly, there are no systematic cost analyses about technologies. When meeting the technical experts from the production line, there was an idea of analysing the relation between the top suppliers and top technical experts and project units. This would make the technology more transparent behind the repairing orders. In other words, the analysis would give information about which technologies are the most expensive, which are time consuming and which have the highest volumes. (Feedback Round 1 2014.) However, at the moment there is no systematic way to do that since the SAP lacks search factors such as supplier or technical expert (Team Meeting 6 2014). As mentioned before, this is an SAP improvement issue inside the team.

Finally, the qualifications of the employees are crucial in order to achieve clear process without rework and data clearing. Qualifications have a positive and negative effect. When an employee is not oriented to the work, there are more mistakes in the total process that there would be if the employee was well oriented. There are a few examples about the unclear roles and utilisation of the know-how of the employees.

Firstly, as already mentioned the management team of the THE DEPARTMENT is responsible for the cost approval of the repairing orders. However, they do not have the sufficient knowledge about the costs of the technologies. One possibility would be that responsibility for the approvals would be transferred to the technical experts. Secondly, the warehouse keeper is responsible for the not-in-stock orders but is not a technical specialist. This can be seen as a minor data quality problem in addition to the other problems of process of the not-in-stock parts. (Team Meeting 5 2014.)

Finally, one example of the unclear roles was found during a meeting with a supplier. It was uncertain, which process the situations belong in, when a spare part is exchanged for a second hand spare part. At the moment it had been a part of the repairing process, but there have been discussions that it would be a part of the purchasing process. In SAP the exchange cannot be seen. (Supplier 3 2014.)

External improvements

Firstly, the internal lead-time is more or less under control but the external part of it is difficult to manage. One known problem is the intermediate stocking by some of the transportation companies. Secondly, SAP is used in Company X but also in the biggest external partners. At the moment, there is no systematic information sharing, which could ease the transparency and data clearing problems. The suppliers have lots of useful information that does not reach the employees in the production line, although it would be needed. The biggest issue is the defect codes; what did the supplier do during the repairing. This information is needed in the production line. Now the employees need to call and inquire about the analysis, when they would like to have the information.

As mentioned in chapter 2, the control of the external part of the supply chain requires deeper quality management through supplier audits in order to improve the cooperation. In the beginning of the project in the discussion with an external supplier, there were a few ideas for improving cooperation by information sharing. Company X should give better defect analysis from the production line and in return the external supplier could send for example an excel table about the defects that were repared. This information could be used for internal SAP as well. (External supplier 1 2014.) With the team manager it was agreed that the cooperation with the key suppliers would be deepened to achieve a more smooth and transparent process flow. (Team Leader 2014.)

However, so that the information sharing was useful for the company’s SAP, it should be in electronical form. Secondly, both companies should use a mutual number for instance the repairing number. At the moment, each document has individual order and offer numbers and there is no connection between the information of the suppliers and Company X. These two improvements would enable the integration of the information to the SAP iPro. (SAP specialist 1 & 2 2014.)

4.6 Control

In this final section of the Six Sigma project, the author will give ideas on how to permanently solve these transparency problems. Firstly, the project Repairing Process Optimization in the production line continues after this thesis. This is why the complete final version of control plan is still in the making. The author presents one version of the control plan (Appendix 7) concentrating on the transparency according to the main focus of this thesis. Secondly, for instance improvements in SAP system are extremely expensive. Consequently, it is the team leader's task to compare the benefit to the costs and make the decision, which ideas would be reasonable to implement in the company. This needs to be agreed with the department manager.

The control plan follows the steps introduced in the theory chapter 3. There are seven steps in creating a control plan. Firstly, the author has listed the process steps that need to be improved. Secondly, resources, data and other requirements, that are needed to perform the process step, are listed. Thirdly, the author indentified the characteristics for instance amount, quality, and time for these requirements. Fourthly, the characteristics need to have specification limits; the minimum and maximum levels for them were determined. Fifthly, there need to be some kind of frequency or sample size to prove that the process is inside its limits. Finally, it needs to be defined, how to prove that the process is under control, and what is the reaction plan when it goes out of control.

Firstly, in the very beginning in the process, the defect information from the production line does not reach the warehouse keeper. To improve this step, the defect text will be printed, when the part enters into the stock. This enables the analysis about the frequencies about the reasons of the repairing. The process instructions must be updated and schuling arranged so that the employees are aware of the changes.

Secondly, it is less transparent whether all the parts that cost less that 400€ are scrapped or not. An update to the process instructions might be necessary. Thirdly, the requirement for the repairing offer is transportation of the part to the supplier. Furthermore, the cost approval is done individually for every repairing order. The technical experts expect the repairing process to be as short as possible. At the moment, they do not reach information about the movements or delays in the process. To solve this problem, it needs to be cleared if it would be possible for SAP to send notifications about some of the movements instead of all of them. Cost approval commissions with the key suppliers would reduce the lead-time with the key partners. This means for instance quartal contracts about the costs. In the contract, the maximum cost per quartal is determined and after the time is over a new commission is made. Nevertheless, trust is necessary when making this kind of changes.

The repairing price should not be over 60% of the new price, when making decision about the repairing. However, the rule should be proved to determine if the 60% of the new price is the right percentage. Moreover, the management team gives the approval for the costs, even though they do not have the technical knowledge about the spare parts, and what could the repairing of it cost. To ensure that the suppliers set a correct price, it would be a good idea, that the technical experts made the cost approval or that they would be more conscious about the costs in general. Now the information about the costs is not systematic shared with the technical experts. In addition, the volumes and costs should be analysed monthly in order to make the relation between the technologies, volumes and costs more transparent.

After the repairing the spare part is transferred back to the stock or back to the customers. However, no defect analysis about the repairing is delivered. The technical experts say that the analysis would be necessary in order to receive in-depth information about the technologies. For instance, the defect analysis would reveal if the same technologies were repaired everytime because of the same reason. One idea is that the key suppliers send an monthly Excel table about the defects with the data that is needed in the production line

Finally, the data quality should be improved in SAP iPro in general. One of the main reasons for the transparency problems is that all of the information is not documented in SAP. The most important information would be defect codes, serial number, quarantee time and new prices of the products. However, it is the department manager's task to determine the right balance between the information system costs and transparency.

TABLE 4. Summary about the Control Plan.

Goal	Before	To-Do	Responsible
Defect Text from Production Line known	Defect Text does not reach Warehouse	Defect Text printed with the spare part	Department A Team Warehouse Keeper
400 € strict obeyed	Company Policy less transparent	New price always > 400 €	Warehouse Keeper
1. Transparency to Transportation 2. Technology Analysis 3. Cost Approval Comissions	1. Customer unaware about the movements 2. No analysis before 3. Cost approval for every order	1. Notifications about specific movements 2. Monthly Report 3. Quartal Contract	Department A Team Cooperation: External Suppliers
1.Transparency: Rule 60% 2. Cost Approval through Technical Experts	1. Company policy unclear 2. Cost Approval trough team Department A	1. Define the company policy 2. Cost Approval through Technical Experts	Department A Team Cooperation: other departments
Analysis about Defects / Frequencies possible	No Defect Analysis from the Suppliers	Defect Analysis to Technical Experts	Department A Team Cooperation: Technical Experts External Suppliers
Data Quality in SAP	Untapped fields	More effective usage of the fields	Department A Team Warehouse Keeper

Table 4 above summarized the implementation part of the control plan. As the beginning of this chapter mentioned, the control plan will be developed until the end of the project in November. However, these are the main issues about the transparency that should be improved.

5 CONCLUSION

This chapter will go back to the research questions and hypothesis and conclude the results and findings of this thesis. Additionally, the author will evaluate the reliability and validity of the thesis and give some suggestions for future research.

5.1 Results and Findings

The author wants to review to the research questions in this chapter. The main research question of this thesis was:

> How to increase information transparency in the repairing process of the spare parts in the production line in Company X?

The study appoints the meaning of the information systems in the supply chain. Moreover, information transparency and information sharing simplify complex processes. Warehouse and transportation management is balancing between internal and external requirements and expectations. Clear roles, data quality, information sharing and visibility, cooperation with external partners and cross-organisational cooperation are the key elements in the process management and increasing transparency.

The author had some secondary guestions in order the focus the research even more:

- How does Company X use the Lean Six Sigma method?

Through the case section, the author followed the project steps that were made during the project in the case company. As it can be seen in chapter 4, the project flow can differ from the theory. It depends on the type of the project. In this case, the project team could follow the steps as stated in theory until the ninth step. The rest of the project steps were/are made simultaneously.

- What elements cause less transparency in the process?

During the research, problems in the information flow were found. More precisely, the lack of information sharing and uneffective usage of the information system SAP iPro were causing these problems. There is lots of information available but it is not integrated in SAP iPro. Moreover, information is not efficiently shared cross-organisationally between the teams or with the external suppliers.

- How the repairing process can be improved through the project?

As a result, the author found many improvement ideas through the project. The author finds the following three the most reasonable changes for the process considering transparency. Firstly, the untapped SAP fields should be activated. The most important fields would be the actual new price of the spare part, serial number and guarantee time. Secondly, there is an internal customer need for analysis about the volumes and the costs. Monthly analysis would bring transparency and awareness about these issues for the team and for the other departments. Finally, the defect analyses from the production line and from the suppliers are necessary. This would increase both cooperation with the external suppliers and the cross-organisational cooperation.

Finally, the author had some hypothesis for the research:

- Problems in the information flow cause less transparency.
- Because of less transparency the process is not cost-effective.
- Because of less transparency the lead-times are longer.

As stated earlier, the author found issues in the information flow that cause less transparency. Less transparency causes longer lead-times for instance because of the need of searching for the information needed or because of dataclearing. However, through this research the author cannot say if the process is less cost-effective, although there were cost related issues as well. For instance the team, which has less technical knowledge, is responsible for the cost approval. It causes less transparency in the process, but it is not necessarily a cost-effective issue.

5.2 Reliability and Validity

Reliability is the consistency or stability of the research (Johnson, Christensen 2014, 166). The data was collected through the project. After every conversational interview, the author went the materal through with her mentor or with the team members. Additionally, after every project step, the findings were agreed with the project team and the department manager. Thus, the data is considered to be reliable.

Validity refers to the accuracy of interpretations or actions based on the research (Johnson, Christensen 2014, 172). Concerning the validity, the author was able to answer to the research questions. Furthermore, the case company is able to benefit from the study, since the author was able to present the issues causing less transparency. Therefore, the author firmly believes this study to be valid.

5.3 Suggestions for Future Research

In this chapter, the author presents some ideas on how the project continues in Company X. Moreover, suggestions for research after the project are given as well.

As mentioned before, the project continues until November 2014. The next steps for the project are to sharpen the control plan, agree on the improvement ideas with the department manager and inform the other parties of the process about the changes. The task of the department manager is to decide, which of the improvement ideas bring benefit over the costs. Furthermore, a new process capability analysis and control chart about costs will be run after the changes have been made to test the benefit of the project.

In the theory section about logistics was discussed that it is not enough to improve the supply chain internal, when the external part has a major effect as well. This idea could be transferred inside the company as well. The team is responsible for the repairing process and its budget, however it is not enough that the ideal process flow and cost-effectiveness are achieved from the department’s point of view. The repairing process and its co-processes inventory of the NPM warehouse and purchasing process have a huge effect on the production of the end commodities.

Consequently, it should be defined, how to improve the cross-organisational cooperation between the departments and find a balance between the different needs and goals of the departments. Firstly, The leaders of the departments could meet each other and discuss about the different points of view and this way share some information with each other. The author finds this to be the first step of increasing information sharing. In this project there are two internal parties; the team, which is responsible for the repairing process and its budget, and the customers in the production line, who do not want any delays in the production of the end goods. The common benefit should be determined so that the both parties are committed pursuing the ideal process flow.

Secondly, the external partners have a significant role in achieving the ideal process flow. As mentioned in the case section, the team leader of the department would like to improve the cooperation with key suppliers. However, further research is needed about the barriers that might occur between internal and external parties. The author discussed about these barriers in the sub-chapter 2.2 about information management. There are four types of barriers: cultural, financial, technical and organizational. Firstly, cultural barriers between the parties can appear because of different kind of regulation about the information security and capabilities. The external partner might not be allowed to share information or more likely they do not systematic collect the information needed to be able to forward it. Secondly, the key suppliers might use different kinds of information systems or they do not use systems such as SAP at all. This can cause technical barriers in information sharing. Thirdly, depending on the size of the supplier they might not have resources to invest better functioning information management and systems. These financial barriers are closely connected to the technical issues. Finally, as an organizational barrier, the processes of the two parties might be so disconnected that the information sharing and integration is impossible.

In conclusion, these were the suggestions for future steps and research for the project and for the time after the project. Both internal and external points of view need to be considered, in order to achieve the ideal process flow that fulfills the aims of every party of the process.

6 SUMMARY

The main objective of this thesis was to find out, how to increase transparency in the repairing process in the production line in Company X. The case company commissioned the study. The aim was to investigate transparency issues from the information flow point of view. The author concentrated on the information sharing and information systems. A secondary goal was to study, how Company X applies the Six Sigma method in the project, and what kind of elements cause less transparency and finally, how the repairing process can be improved through the project.

The author applied mixed research methods. The author collected qualitative data by observing in team meetings and by informal conversational interviews with the team members and other parties of the project. Additionally, quantitative data was taken from SAP iPro system, which is a large logistical database in the company. The quantitative data was used for statistical analysis such as capability analysis.

The study demonstrated the signifigance of the information systems in the supply chain. Moreover, information transparency and information sharing simplify complex processes. Warehouse and transportation management is balancing between internal and extrenal requirements and expectations.The main internal problems were found both inside the team, which is responsible for the repairing process and in cross-organisational cooperation. Firstly, the team in the department is able to improve the data quality in SAP iPro. Better quality would lead to better documentation of the repairings and thus, to a more transparent process flow. Secondly, the study showed that there is a lack of information sharing between the departments. Different transactions in SAP are not connected, and more importantly the departments in the production line do not receive information about the volumes and costs of the repairings. Finally, lack of information sharing is an issue with external partners as well. There is a customer need for defect analysis of the repairings. At the moment, there is no information about the repairings made by the supplier in the case company.

The author found the following three the most reasonable changes for the process considering transparency issues. Firstly, the untapped SAP fields should be activated. The most important fields would be the actual new price of the spare part, serial number and guarantee time. Secondly, monthly cost and volume analysis about the repairings would bring transparency and awareness about these issues for the team and for the other departments. Finally, the cooperation should be deepened with key supplier, so that the information sharing about the repairing cases would be possible.

This study generated some suggestions for possible future research as well. Firstly, the project continues after this thesis. The next steps for the project are to sharpen the control plan, agree on the improvement ideas with the department manager and inform the other parties of the process about the changes. The task of the department manager is to decide, which of the improvement ideas bring benefit over the costs. Furthermore, a new process capability analysis and control chart about costs should be run after implementing the plan. The analyses will tell about the benefit of the project.

Secondly, the cross-organisational reform might be necessary. It should be defined, how to find a balance between the different needs and goals of the departments and what is the ideal way to divide the responsibilities of the repairing process. Finally, after improving the internal issues, the process optimization continues to external part of the process flow. The author suggests analysing the key supplier in order to investigate the possibilities to share information and barriers that might occur.

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