Improving engineering process productivity when visualizing waste and mitigating variation

A case study performed at an automation company using Lean Six Sigma principles

by

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ABSTRACT
The project is carried out as a case study at FlexLink AB, a global company providing factory conveyor solutions, with head quarter in Gothenburg. Focus has been on the project execution phase called Project Engineering (PE) at four different operating units in Europe. The PE process provides the final project design by using modular designed conveyors; the output of the process is a CAD model and final detailed drawings sent to the assembly workshop where the physical execution takes place.

The study investigates the PE process in terms of variation and noise factors. Hence non-value added activities throughout the process were identified by interviews, observations and conduction of a survey. As a backbone throughout the project, the principles of Lean Six Sigma (LSS) has been used. The project aims at identifying critical-to-quality factors of the PE process but also investigating the feasibility of using LSS as a method within project execution at an automation solutions company. An existing gap in documented research has been identified for practical examples of LSS and its applicability in the automation industry.

Major findings of the study were an rejection of the existing measurement system and three critical x-factors with remarkable impact on the investigated process and its output. The x-factors were; (i) use of different CAD-tools, (ii) re-drawing and (iii) handover documents – assembly. They all contributed to unwanted non-value-added activities throughout the process. The project enabled possible saving of 1.4 MSEK. In addition, it was concluded that LSS was a feasible method to use for an automation engineering process. Most fruitful was the establishment of a common technical language and enabling of cross-sectional agreements as LSS forces. The thesis work can prove evidence for additional strength of LSS as a method with abilities to reach both organizational and national borders.

Keywords: Lean Six Sigma, LSS, Lean, Automation, Factory Automation, Project Engineering, Waste Elimination, Modular Design, Non-value-added activities, Process Noise Factors

List of abbreviations and company terms

AE – *Application Engineering* , the pre-step of the Project Engineering department, handing over a first layout together project with the customer quotation.

ARAS – New PLM system developed for FlexLink to be used globally starting 2017.

EBIT - Earnings Before Interest and Taxes, i.e. the profit of the company from the financial statements.

EOPL – Name of the Polish FlexLink Engineering and assembly unit in the study.

FUTAC – *Full time accounting*, company rules in how to report time, implemented in June 2015

FLDT – *FlexLink Design Tool,* a CAD tool developed by Engineering Tools department at FlexLink. Aimed for making layouts of projects and to produce full designs of small and medium-sized projects.

FlexCAD – The newly set standard CAD library data base used at FlexLink. Meaning the desk area were all the standard CAD files such as Conveyors, Screws and Brackets are stored.

LSS – *Lean Six Sigma,* methodology for process improvement used throughout the project.

Movex – The ERP system used at FlexLink today, by 2018 to be replaced with SAP.

Non-productive time –company definition of the time that the engineer spend but is not reported as project time, i.e. not paid by the customer.

PE – *Project Engineering*, the department at FlexLink were the study is focused on.

Production Binder – The complete set of documents including drawings, materials lists etc., handed over to the assembly in EOPL.

PSD – FlexLink's spare part company in based in Poland handeling the central warehouse of internal material.

Recovery Rate – The company's financial term for the total cost divided by the total amount of hours. It gives a cost per hour that will be used to calculate how much a chargeable man hours would cost when invoicing and calculating costs.

T-codes – The codes used to report non-productive time, e.g. T10, T20, according to the FUTAC company standard of time reporting.

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1. Introduction

The Master's Thesis project is carried out at FlexLink AB in Gothenburg, performed by Erik Gerremo for the Master's programme *Quality and Operations Management* at Chalmers University of Technology. Examiner and tutor from Chalmers is Peter Hammersberg and mentor at FlexLink AB ("the company") is Svante Anderholm.

1.1 Academic background

The general idea and purpose of Lean Six Sigma is according to Sheridan (2000) to combine the two methodologies of Lean and Six Sigma, and integrate adequate elements from each methodology together. Traditional Six Sigma is defined as a methodology used to solve problems in a structured way using the five steps of *Define, Measure*, *Analyze*, *Improve* and *Control*. According to Bendell (2006) there are few practical examples of this interactive methodology documented in literature. This statement is confirmed by Pepper & Spedding (2010).

Most of todays' documented Six Sigma research covers traditional Six Sigma used for industry processes with related data and process parameters, sometimes referred to as Operational Six Sigma (Temblador & Ramirez-Galindo, 2011). The amounts of research identified directly related to automation industry are few. No single practical example of a Six Sigma investigation of a project execution phase within automation solutions industry has been identified.

With project execution phase means the designing of an automation system, in this particular case; mainly putting together existing sub-assembly parts with external parts or might also additional new designed parts when developing a new solution. It is not fully likely to equate product execution phases of the automation industry with the product development phases. However, the field of product development has been screened through as well in order to see if there are any synergies or connections in between those two. Most of the available Six Sigma research connected to product development related to Design for Six Sigma (DFSS), which mainly covers the development of a totally new product with new related processes.

Therefore it was considered a gap in the research and documentation of existing Six Sigma investigations made on the automation industry and related product execution phases.

1.2 Company background

FlexLink AB is a developer and manufacturer of automated conveyor solutions. They provide production equipment to several different industries such as the medical, automotive and electronic industry and delivers solutions to both different machine producers and end-users. An example of a conveyor system provided by FlexLink can be seen in figure 1

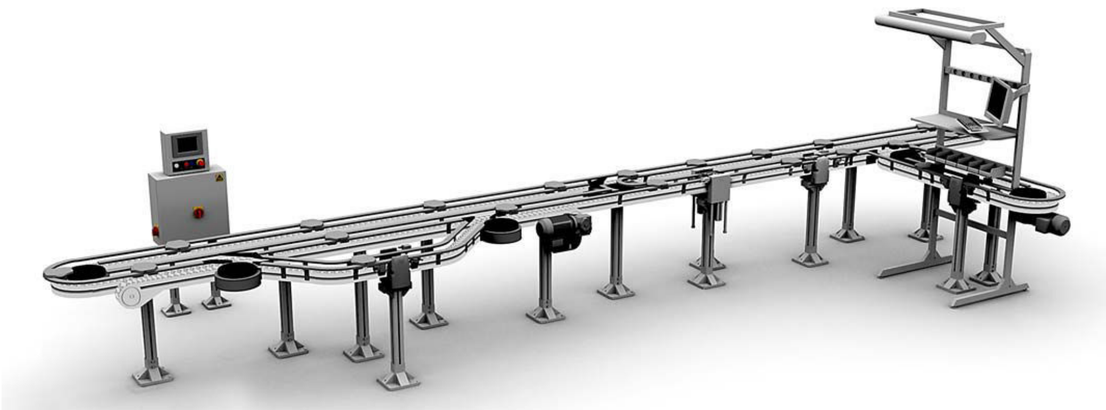

Figure 1 A FlexLink designed conveyor system (FlexLink, 2017)

The company has operating units in 30 countries spread around the globe (FlexLink, 2016). An operating unit consists of; Sales, Application Engineering (AE), Project Engineering (PE), Assembly and Installation. Where Sales is responsible for the initial customer contact and the prize of the solution. Application Engineering calculates is in near contact with sales and calculates the cost of the project and generates a first layout of the solution. Project Engineering makes the final detailed drawing and the CAD model of the project, which is later handed over to assembly making the physical completion of the project ready for installation. An overview of FlexLinks Chain of operations can be seen in figure 2,

Figure 2 An operating unit's chain of operations

In Appendix II a more detailed figure of the company's chain of operations, according to their quality management system is shown. In addition to the operating departments, other support departments exists e.g. *Purchase*, *Finance*, *IT* and *HR*. Focus will be on the *Project Engineering* (PE) department and the costs and activities related to that department. PE also has its own supportive functions; *Project Management* (PM) and *Project Administration* (PA) whom work in parallel and hence also affects the project process and project time. Therefore the problem will not only be delimited to the Project Engineers but also the support functions.

The first focus of the project was a trend seen in an increased *recovery rate* for the entire organization. The *recovery rate* is defined as the company's total cost divided by the total amount of hours spent. The increase of the *recovery rate* with 10% therefore means the cost per spent per hour, has increased with 10%, i.e. achieving less payback per added work. The *recovery rate* is used when the company is budgeting for the next year. It further affects the *Earnings Before Interest and Taxes* (EBIT) i.e. the company's profit. Figure 3 shows an example of an annual EBIT calculation for one operating unit in the organization.

Net Sales - Total	1 342
COGS - Total	-913
Gross Profit	**429**
Gross S&A	-1 000
Recovery	267
Net S&A	-733
Amort. Intangibles	0
Oth. Oper Inc./Exp.	0
EBIT	**-304**

Figure 3 EBIT calculations

Example of costs that are included in the Recovery Rate are overhead costs such as rent and heat but also salaries and shared costs for different support functions such as HR and IT departments. The project was not considered to have the ability to have an impact on the fixed costs. What was likely, in the Recovery Rate calculation, for the project to have an impact on is the number of chargeable hours in the projects.

It means how big proportion of time that is reported as actual project work, the company definition is Engineering time, which is the number of hours paid by the customer. The rest of time is reported as "non-productive time", it can be supportive and administrative tasks that are not directly related to projects, e.g time reporting or company meetings. In figure 4, the percentage of chargeable hours for Project Engineers and consultants for one unit is shown. Those numbers are therefore based on the proportions of of time reported as either project time or non-productive time, by the employees.

Number of hours at work per person	*1 816*	*1 816*
% Hours at work on chargeable business	*71%*	*90%*

Figure 4 Amount of chargeable hours engineers (71%) vs. consultants (90%)

The S&A costs from the EBIT calculation in figure 3, is the category where all the man-hours will end-up in the financial statements, if they are not used on *Cost of goods and services* (COGS). Since the hours are already budgeted, they become an administration cost if they are not spent on projects and hence affect the efficiency rate and the project margin.

The ideal cost distribution of a project at the company is visualized in figure 5, meaning one third of the costs should be spent on the *cost of hours* i.e. *project hours*, and the other two thirds on *internal* and *external material*.

Figure 5 Ideal cost distribution of a project

The company's goal is to spend 85% of the *project hours* on actual, value-added project work. However, this is not always possible due to several reasons. It may occur that non-value added activities hinder the actual project work to take place. Examples of this non-value added work could be various types of waiting, support, training, IT issues etc. There is an expressed need from the company to get the non-value added work mapped-up and find out the underlying causes and drivers behind this.

For every project, at any operating unit throughout the organization, the amount of time spent on different activities is reported and stored in a time reporting system. At the Swedish unit, *Etimes* is used*,* an application provided by *Intentia*. Existing data of reported project time by Project Engineers and Project Managers exist. The time spent by the engineers is reported as either project time, that is paid by the customer or non-productive time, which will end up as S&A costs on the EBIT.

There was an expressed need to map-up the current state of the non-productive time and to analyze and try to find the underlying causes of that time. If managing to decrease and eliminate some of the unwanted non-value added time in the projects, it will decrease not only the *S&A* costs but also the Recovery Rate*,* shown in figure 3, in the annual results and provide a higher profit for the company. The non-productive time will sometimes be referred to as *admin time* throughout the study.

A reduction of the level of non-productive administration makes the company more profitable and efficient, which favors not only the EBIT result but also the next internal customer in line, *Assembly.* They will receive a more accurate and predictable delivery. By the end, a more efficient Project Engineering process would also affect the end-customer in a positive way, since it enables a shorter delivery time.

In parallel with this study, an additional Master's Thesis project was going during the same period. It investigated the same Engineering process but focused on the actual engineering process and the time spent within projects that is paid by the customer. Instead of the non-project time as this project was focused on, that can be seen as outer noise factors interfering with the process. Since both projects cover the same process, some facts and figures from that Thesis report will be referred to in this report.

1.3 Problem definition

The unwanted trend in the increased Recovery Rate was the initial focus of the project, it was after has been research made, scaled down to a contributing factor to the Recovery rate. This factor, was the amount of administration time or non-value added time throughout the Engineering Projects.

An additional aggravating circumstance is that FlexLink has a standard way of working, according to their Quality Management System. However, any operating unit does not work in an identical way as one other. It means their processes are normally adapted after local culture and circumstances. The reported project time is an example of an unwanted variation. Since it varied the way it was reported and which time was being reported as project time or not.

1.4 Purpose

The purpose of the Master's Thesis is to investigate and map-up the variation of *non-value added* time within an engineering project execution phase in the automation industry, by using *Lean Six Sigma* (LSS) methodology. Aim is to identify critical to quality inputs of the process and try to turn those into controllable variables and hence improve the output of the process by making it more controllable.

Hence, deliver a set of recommendations for improvements based on the findings. The recommendations should be feasible to implement on global level. In addition an analysis of the feasibility of using LSS methodology on a certain Automation Engineering process will be carried out.

1.5 Research questions (RQ's)

- RQ1 –Which are the main critical to quality factors, x-factors, contributing to unwanted variation of the project execution process?
- RQ2 - What actions should be taken in order to mitigate the impact of those x-factors and steer them into controllable factors?
- RQ3 – To which extent was it feasible to use LSS methodology in order to improve a project execution phase within an automation solution company?

1.6 Delimitations

The project will be carried out from 2016-10-03 until 2016-02-15 at FlexLink AB in Gothenburg. Due to the amount of time and resources available, all operating units cannot be investigated. Therefore, delimitation has been set to focus on the European operating units primarily. Four operating units including Sweden, Poland, Germany and England have been chosen for the study. These four units are by the company considered diverse enough to represent the European departments. However, care will be taken so that the findings from the project can be feasible for the global organization and minimize the risk of sub-optimization.

2. Method

The Lean Six Sigma approach, with the DMAIC process, will be used as a backbone throughout the project. The DMAIC process is a change process consisting of five steps; *Define*, *Measure*, *Analyze*, *Implement* and *Control* (George et. al, 2005). Most focus will be put on the first three steps, *Define*, *Measure* and *Analyze,* which is also the approach of Lean Six Sigma, where focus is set to clearly define the problem before taking action. However, an adequate hand-over will be made, so that the findings of the project can be both implemented and controlled after the study has been finished.

The empirical part of the report will be divided into each phase of the DMAIC process; a description of each phase will also be included in the beginning of each phase. After the empirical results have been presented in the DMAIC phases, all the results from the empirical part will be summarized in a section called *Results.*

2.1 Research strategy

The project was carried out as a case study, taking place at FlexLink AB and the four operating units in Europe, emanating from the headquarter in Gothenburg. This means the study consider a single example at one company. It indicates the applicability of the results will be limited. However, Bryman & Bell (2011) claims that some of the most useful results within the field of management and business research come from this type of research.

Action Research was applied throughout the research since the researcher was located at the company throughout the study and to some extent collaborated with the organization were the study was carried out.

A Qualitative research strategy was used throughout the study. Qualitative data was collected from semi-structured interviews with the stakeholders. Qualitative data is preferable when not wanting to steer the participants of the data collection into already known believes, but rather come up with new theories (Bryman & Bell, 2011). Based on the results of the qualitative interview data, a survey was conducted in order to collect quantitative data, which is more useful when testing existing theories (Bryman & Bell, 2011). From the survey it was also gathered more qualitative data consisting of comments and diary notes filled out by the participants. Mainly inductive research were carried out, implying that theory was created and sought after the result was known rather than testing a hypothesis (Bryman & Bell, 2011). However, some frame of references were used in order to give input to the execution of the study and to provide some background facts about the LSS methodology..

2.2 Research Methods and data collection

Below the different research methods that has been used are presented. A research method is a special tool or technique used to collect data (Bryman & Bell, 2011).

2.2.1 Semi structured interviews

During the visits at the different units Project Managers, Project Engineers and Project Administrators were interviewed. In Poland, Sweden and England, face-to-face interviews were held at each sight. Interviews with the German unit, were held through video meetings. Semi-structured interviews were used as interview technique. This technique generates qualitative data (Bryman & Bell, 2011). Semi-structured further gives the opportunity to ask follow-up questions and enables to dig a deeper understanding of the causes behind the experienced problems (Bryman & Bell, 2011). Snowball sampling was used in the selection of interviewees. It means initially starting with a group of interviewees and let the result from these interviewees bring further new people to interview (Bryman & Bell, 2011). In order to ensure the right representation of the interviews, an initial plan of approximately how many interviewees of each category and operating units was made. This type of sampling is called quota sampling (Bryman & Bell, 2011). However the initial plan was only used in addition to the Snowball Sampling, which was the major driver throughout the selection of interviewees.

In total 30 interviews were held, whereof 16 of them were made throughout visits made in Poland and UK. The rest of the interviews was held in Sweden and on video link with Germany.

2.2.2 Combined survey and diary

A combined variant of a survey and diary, to be filled-out by the attendants in the study, was chosen as self-completion questionnaire design. According to Bryman & Bell (2011) the strengths of using a diary as a method are that it covers the attendants' daily work and thus minimize the risk of the attendant to forget information to provide. A diary can be both structured and of "free text" and hence enable both qualitative and quantitative data (Bryman & Bell, 2011). One common drawback is the risk of lost interest and decreased dedication over time. The study used a combined form of both free text and a structured category based selection. One Project Engineers at the office in Gothenburg tested the form before it was sent out. This was made in order to see if the information was clear enough or if any categories were lacking or if there were any misinterpretations.

The sample of participants was chosen using a non-probability quota sampling. Snowball sampling was used when choosing the participants of the survey, based on the result from the interviews. It implies a risk of getting a biased sample. However, consideration was taken so that participants were selected; both those who had a positive attitude to renewal and change and those that had a more critical eye. Aim was getting a cross-section representing the population of the European units. Principles of Change Management principals were also used when conducting the survey, most important was to clearly explain why the study was carried out and what was in it for the participants Strebel (1996).

2.2.3 Structured Observations

In parallel with the interviews at the different units, observations have also been carried out. Structured observations are useful as a method in order to see the behavior directly and identify certain details, which may risk not getting recorded throughout surveys and interviews Bryman & Bell (2011).

2.3 Ethics of the research

The four main principles of ethics developed by Diener & Crandall (1978) have been used throughout the study in order to cover and include the ethical aspects. In the sections below each category will be explained and how it was taken into consideration for this particular study.

Harm to participants

The research should not in any aspect harm the participants. It could consider either physical or psychological harm. It is of importance to inform the participants clearly what the purpose of the study is and that it is anonymous and declare that no harm, what so ever, should ensue their participation.

The participants in this study were accurately informed of the purpose with the study, and that their contribution was aimed to help the organization to grow and improve. In addition it was communicated from central management to all the participants that no one individual would be after checked or set to account for any opinion given.

Lack of informed consent

The participants should be given information enough to make the decision whether or not to participate. The researchers should clearly present their role of researchers and not disguise it into something else.

Information in form of sent out background and info and video meetings were held in order to present the study. The participants were encouraged contacting the researcher at any time before and throughout the study if they considered they had not received enough information or had any questions.

Invasion of privacy

No participants should be concerned of getting intruded into privacy. To remain anonymous as a participant has been central in the aspects of the study. It has clearly been communicated when making interviews and in all information related to the survey.

Deception

The last principle entails the risk of using the result of the study for other purpose than what has been communicated. This should be avoided since it is unpleasant for anyone to be exposed for and since it may contribute to decreased reliance against researchers.

The participants in this study have been clearly informed about the purpose with the study and have been offered to see the results of the study in order for them to see that their input and contribution is valuable.

2.4 Trustworthiness

Bryman & Bell (2011) refers to four main principles when taking into consideration the trustworthiness of the study; *transferability*, *dependability*, *confirmability* and *credibility*. *Transferability* means to which extent others can apply the findings of the study. In this study the result would be most useful for businesses with similar world wide engineering processes in need of variation analysis and to state as an example of LSS improvement investigation of a project execution phase within technical solution industry.

The *dependability* consider audit of the results and keep records of all collected data, so that it could be examined and moreover that the result is not just a tip of an unknown iceberg of hidden information. All records and notes have been stored from the study and are electronically backed up. However, in qualitative research the data is often massive and could be difficult and time consuming to for an external person to go through.

Credibility has taken into consideration mainly by using respondent validation by letting the attendants of the study take part of the result but also to let other parts of the organization and the supervisor at the university to audit the findings. Both existing data and newly collected quantitative and qualitative data from interviews and the survey were used in order to get a level of triangulation into the study. Last principle is *Confirmability* and concerns objectivity. As previously mentioned the study has been carried out as Action Research and full objectivity is by that sense impossible to obtain and a level of bias thus occur.

3. Theory

This section covers the theory base of the problem. Providing what is already scientifically known about the problem and which information that is lacking. The theory has been used as frame of reference and input in assistance to carry out the study and more theory have been added throughout the study to supplement the empirical result.

3.1 Lean Six Sigma

The general idea and purpose of Lean Six Sigma (LSS) is according to Sheridan (2000) to combine the two methodologies of Lean and Six Sigma, and integrate adequate elements from each methodology together. According to Bendell (2006) there are few practical examples of this interaction documented in literature. This statement is confirmed by Pepper & Spedding (2010) four years later. They further conclude the combination of the cultural and philosophical thinking of Lean combined with the structured data oriented methods and theories of Six Sigma as powerful improvement methods. Together, Lean and Six Sigma can establish a powerful tool or method to achieve success in change or process improvement work by creating strong knowledge of the process (Pepper & Spedding, 2010).

The concept of LSS is relatively new as a concept; Shaffie & Shahbazi (2012) has listed the main purpose and metrics of Lean Six Sigma. These purposes and metrics have been used to explain the concept of LSS and the possible winnings of using the methodology.

Traditional thinking vs. Lean Six sigma

LSS is in the same manner as Lean not seen as a final state that an organization ends up in, but instead a continuous journey away from what could be described as "traditional thinking" and is shown in figure 7. The traditional thinking of organizations is more cost oriented than focused on solving root faults and errors of the product and process. Traditional thinking is in general more focused on blaming the people rather than the process. The hierarchical structure is in LSS thinking replaced with a focus on empowered teams. LSS further stands for a customer oriented pull think in its operation rather than an internal company focus.

Figure 7 Distinctions in traditional thinking vs. LSS thinking

LSS - Reduce operational cost and risk
The first goal is defined as "Reduce operational cost and risk", which means to make the organization more efficient and predictable and to reduce costs caused by weak quality. The cost can be divided into Tangible and Intangible costs. Tangible cost means "hard" costs that can easily be counted and measured. Examples of Tangible costs could be the occurency of rework, if a task or a step in the process needs to be done multiple times. Inspection is another example; this is a step that is basically non-value added for the customer if the job would have been done in the right way from first. A third example is process waste if there is a step in the process that does not change the produced product or service, e.g. to make a hard copy, scan documents or get a signature on a contract or document.

Intangible cost is the contrary term of Tangible cost. It means costs that are more difficult to detect and trace. One example is the cost of poor quality and customer dissatisfaction, which can render in lost sales and a bad customer reputation. Another example is the cost of lost knowledge due to lack of knowledge storage or poor documentation of previous experiences.

Increase revenue
Another objective of using LSS methodology is according to Shaffie & Shahbazi (2012), to put focus on sales instead of costs as a major metric. Possible projects could be to focus on hit rate of quotations and the trend in rate or the possible variation of the hit rate. The main objective is to get an increased understanding of the customer needs and attracting more.

Customer satisfaction
Deeply investigation of customer satisfaction is another common focus area of LSS. Approaching customer satisfaction and dissatisfaction in terms of variation and understanding the patterns and factors causing this variation. Aim of this approach is, as in traditional Six Sigma, to get control of this unwanted variation and in the end improve customer satisfaction.

Establish a thinking of Continuous improvement
By using a methodology like LSS and following its structured work path it generates continuously improvement of the process and all its parameters. This can help organizations that have a reactive approach to get more proactive. LSS is also useful as a powerful problem solving method and organization working with LSS more likely establishes a common language. This facilitates the setting organizational goals and KPI's and decreases the risk of sub-optimization.

3.2 Transactional Six Sigma

Transactional Six Sigma (TSS) can be defined as Six Sigma used for data not as structured and palpable as manufacturing and production data (Temblador & Ramirez-Galindo, 2011). TSS can be categorized into Six Sigma for *Support areas, services* and *Administrative processes.* Furthermore they argue upon the three different areas largest challenges when applying Six Sigma. The *Support areas*, which could be for example production support or IT service departments, in general have access to measure systems and metrics but they are rarely a part of the companies decision making process and their KPIs are used most internally at each department. *Administration processes* in general has both vague processes and are normally not working with data collection to a significant extent. Shaffie & Shahbazi (2012) states that use of LSS methodology in non-production processes to be feasible and beneficent and that such service processes normally consists of up to 50% of tasks that the customers do not want to pay for.

3.3 Six Sigma used in Product Development

The Six Sigma content related to product development in existing literature mainly consists of research connected to Design for Six Sigma (DfSS). This is a methodology that is not as globally agreed upon as traditional Six Sigma but and not always follow the same cycle as with for example DMAIC from tradition Six Sigma (Bergman & Klefsjö, 2010). However, one of the most commonly used cycles are IDDOV; Identify, Define, Develop Concepts, Optimize, Verify and Validate (Subir, 2002). This is used when designing complete new products with associated new downstream processes.

3.4 Waste analysis

Originating from Lean there is a waste analysis method called TIM WOODS and divides the waste of an organization into 8 categories (iSixSigma, 2017). Below the different categories are listed.

Transport: Considers transport of people, products & information
Inventory: The storage of parts and documentation (more than required)
Motion: Time consuming or unnecessary movements needed to be done; for example lifting or reaching something.
Waiting: When need to wait for information, pieces, tools or something else that hinders the actual value-added work to take place
Over production: Producing more parts or material than necessary
Over processing: For example when process tolerances or product tolerances are tighter than necessary.
Defects: Rework, scrap or a product made incorrect
Skills: Not fully utilize the capabilities of people.

3.5 Non-value-added activities

At the company, non-value-added time and activities are categorized as everything not being reported by the employees as actual project work. By the organization named non-productive work.

Rother & Shook (2003), states that all activities within a company's value stream, which they define as the flow of information or material that contributes to the final product, can be seen as either *value-added* or *non-value-added* activities. Covering not only the manufacturing and their flows, but also from the very first idea of the product until the launch of a developed model or prototype. They further say that equivalent words for *non-value-added* is *waste* or the Japanese *muda* used by Toyota. When it comes to the identification of non-value-added work, Six Sigma and the DMAIC method could be useful for that purpose, Hammer (2002) states that finding the non-value-added work is an easy thing to do, but in fact changing the behavior of the process causing it is difficult.

If non-value-added activities performed by an employee are identified, it does not mean this employee should be just cut-off from the organization if his or her duties would be cut off. Arnheiter et. al (2005) states that losing this employees is contra-productive, since a lot of information and a lot of tacit and intrinsic knowledge risks to be lost. Instead, they argues, it is up to management to re-arrange the organization so that person makes use and are able to contribute with his or her knowledge in a place where he or she contributes with value.

Ahlstrom, P. (2004) argues that non-value-added activities within services and non-manufacturing processes are subjective since the borderline between what is considered value added tasks and administrative tasks could be vague and diffuse to distinguish. It is therefore considered difficult to distinguish what is value added and not and there might be various arguments.

3.6 Process thinking and noise factors

The theory of processes and noise factors are mainly used for technical processes. However, since this study investigates a process of soft values and information flow rather than production flow and technical data, some background theory of process control and noise factors was reviewed in order to give input to systems thinking and divide the different departments apart with system borders.

Begman & Klefsjö (2010) use the P-diagram in order to describe a process or a system with a given input and output. The input to the process is described as signals and the output could either be a product or a service. They further states the terms *control factors* and *noise factors* that are the parameters that are affecting the process and are controllable and possible to adjust and hence control the output. The *noise factors* are unwanted external factors that are affecting the process in an unwanted way. The p-diagriam with its noise factors are visualized in figure 8.

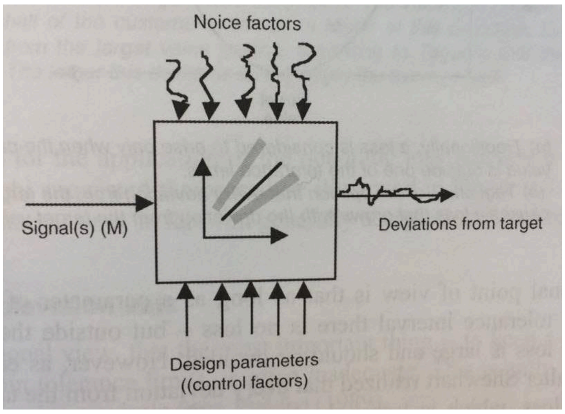

Figure 8 P-diagram and noise factors

The terminology of P-diagram and its different factors affecting the process is according to Chen et. al (1996) the elimination and transformation of noise factors into controllable parameters are the fundamentals of the *Robust Design Methodology.* It aims to minimize the unwanted variation and create the output that the customer wants. Therefore in order to achieve a *Robust Design* of a process output it is important to be able to measure deviations from a clearly stated target (Begman & Klefsjö, 2010).

3.7 Change Management and Cultural boundaries

Strebel (1996) argues there is a human natural resistance against change within organizations. According to him the main reason of the inbound resistance is related to the gap between management, top management as well as middle management, and the regular employees. One the main perquisites, for an organizational change or improvement to successfully take place, is that the sponsor or proposer of the change project must see the situation from the employees perspective. More specifically put themselves in to the shoes of the employees, and see how their actual everyday looks like.

Nadler & Tushman (1997) address organizational change in terms of three phases; Current state, transition state and future state. In which transition state means where the actual change work takes place in order to reach the new state. The three different states are visualized in figure 9.

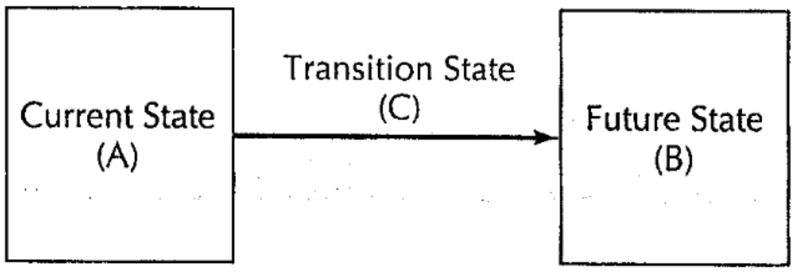

Figure 9 Illustration of the change from current state to future state.

Nadler & Tushman (1997) further pinpoints three main aspects that hinders or complicates the change; *problem of power, problem of anxiety and problem of organizational control.*

The *problem of power* concerns the political environment within the organization, where compete of power constantly takes place between different groups and individuals. The *problem of anxiety* considers the natural resistance against change that exists by nature among humans as a kind of survival instinct. In order to overcome this resistance it is important to clearly communicate *why* the change will have to take place and *what* is in it for the employees in terms of winnings and advantages with the new state. The third aspect, *the problem of organizational control* is related to the challenge of managing and keeping track of the organizational structure during and after the change work and get people out of old habits and beliefs.

Cultural boundaries could also hinder successful change to take place (Strebel, 1996), the complexity increases when having a less homogeneous and more diverse culture. Therefore he states, it is of high importance to make the purpose of the change more explicit when the organization is global and multicultural. This means that the communication must be evident and both formal and informal, and also rooted in local management and organizations.

3.8 Communication – Engineering to Assembly

The communication between Development and Production has been studied. This is an issue in which a widely spread research have been made. However, most of the research found concerns large product development projects with long cycle times. Therefore, it is not fully applicable with the type of engineering and assembly processes occurring at the company where this study has taken place. However, some main principles have been identified and investigated and some synergies have been found.

Wheelwright & Clark (1992) have defined four different patterns of communication occurring between upstream and downstream levels during product development. The different patterns can be seen in figure 10. Example of upstream level is development and a downstream level could be for example assembly or process engineering. The first mode is called *Batch level* of communication. This type of interaction means that the downstream group waits to start until the full design of the product is finished. The design and its associated deliverables will then be handed over in one single delivery. This type of transmission of information may pose a risk of losing details of information regarding deviating and unique parts of the design that the downstream groups are not used to handle.

The second mode is called *Early start in the dark.* It shortly means the downstream unit starts before they have transmitted the final design and information from the upstream unit. This normally takes place when the downstream unit do not consider to have time to wait for the final design. Since the process design and ramp-up of the manufacturing must have enough to be able to start the manufacturing on time. This contributes to a higher risk of surprises and a mismatched process that is adjusted towards another design of the product than what is transmitted. Then all the work made in the dark, can be a pure waste in the worst case.

The third and fourth mode involves a higher exchange of information where knowledge are shared in an early stage of the development or even integrated already from start. This normally takes place at large projects for complex products requiring a long set up time of the downstream activities.

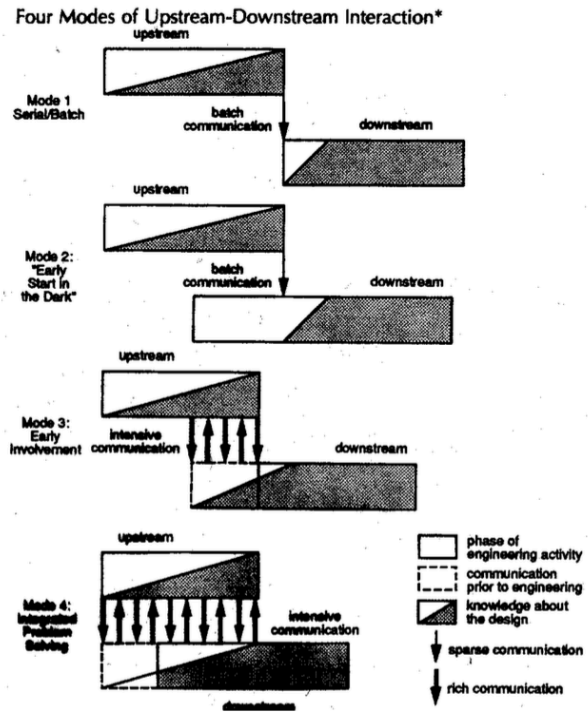

Figure 10 Upstream and Downstream communication.

4. Define

The aim of the Define phase in Lean Six Sigma is to establish a project charter and to ensure the right problem formulation is identified. Project team is being set up and a financial model is developed and approved by the sponsor together with the problem definition. The voice of the customer is collected and processes is being mapped-up (George et. al, 2005)

4.1 Project team and stake holders

The company's standard project charter was used when project sponsor, project team, project scope and financial model were assigned. The project charter enables the project team to get a common view of the project scope (George et. al, 2005). The project charter can be seen in Appendix III.

4.2 SIPOC

A SIPOC analysis was made in order to validate the scope and for the project team and sponsor to get a common view of boundaries and the focus area (George et. al, 2005). In addition, it also provides an overview of the process and its inputs and outputs. In order to avoid cementing old beliefs and to ensure a pull-think when setting the scope, the method Effective Scoping was also tested. However, the results from that perspective did not differentiate in any remarkable way. Therefore, SIPOC was considered qualitative and trustworthy enough to use as scoping method. The results from Effective Scoping can be seen in Appendix I.

4.2.1 Supplier

Application Engineering (AE), the present step in the operations chain, before the Project Engineering, acts as an internal supplier for Project Engineering (PE). However, AE inherently receives their input from Sales Engineering (SE) whom also, in some situations and projects have direct contact with PE. In addidtion to the engineer there is also a Project Administrator who starts the project by activating it as "ongoing" in the ERP system after the budget and time plan has been approved by the Project Manager. The PM has the overall responsibility of the project including budgeting, resource planning and delivery dates.

4.2.2 Input

The input that PE receives is the Sales Hand-over Documents, a Customer specification, a Layout plan for the project from AE made in the FlexLink Design Tool (FLDT). The tool is an in-house developed engineering design tool that creates a first outline of the product. PE also transmits knowledge from the AE department and specific info and tips concerning the current design. Layout drawings made in AutoCAD may occur at some units.

4.2.3 Process

The PE process is where first focus has been set. The processes with its pre-steps and succeeding steps are visualized in figure 11. A more detailed process description of the PE process itself is shown in figure 12, starting with a transmitted project plan and ends with a final drawing and hand-over documents to assembly and the end customer. The process map in the figure has been produced together with the other ongoing thesis work at FlexLink (Larsson

& Sadriu, 2017). Those steps can be seen as the operational steps performed by the Project Engineer.

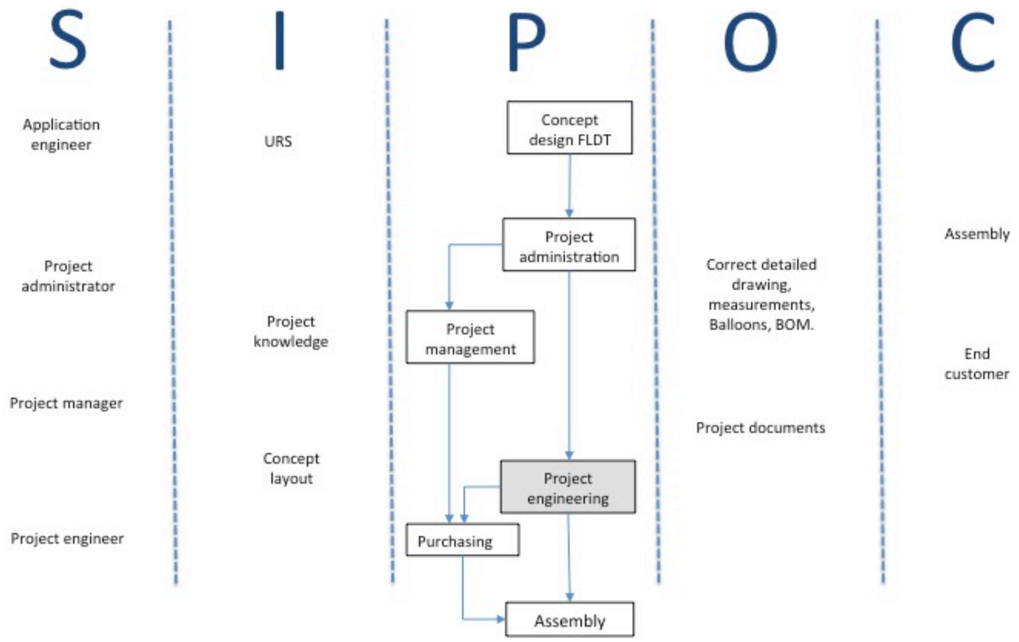

Figure 11 SIPOC analysis focused on the Project Engineering process.

4.2.3.1 Detailed engineering process

The Project Engineering process is shown below in figure 12, each step has been identified together with the Project Engineers and Project Managers. It is focused on what they do in reality rather than how their process is defined as according to quality management system shown in appendix II.

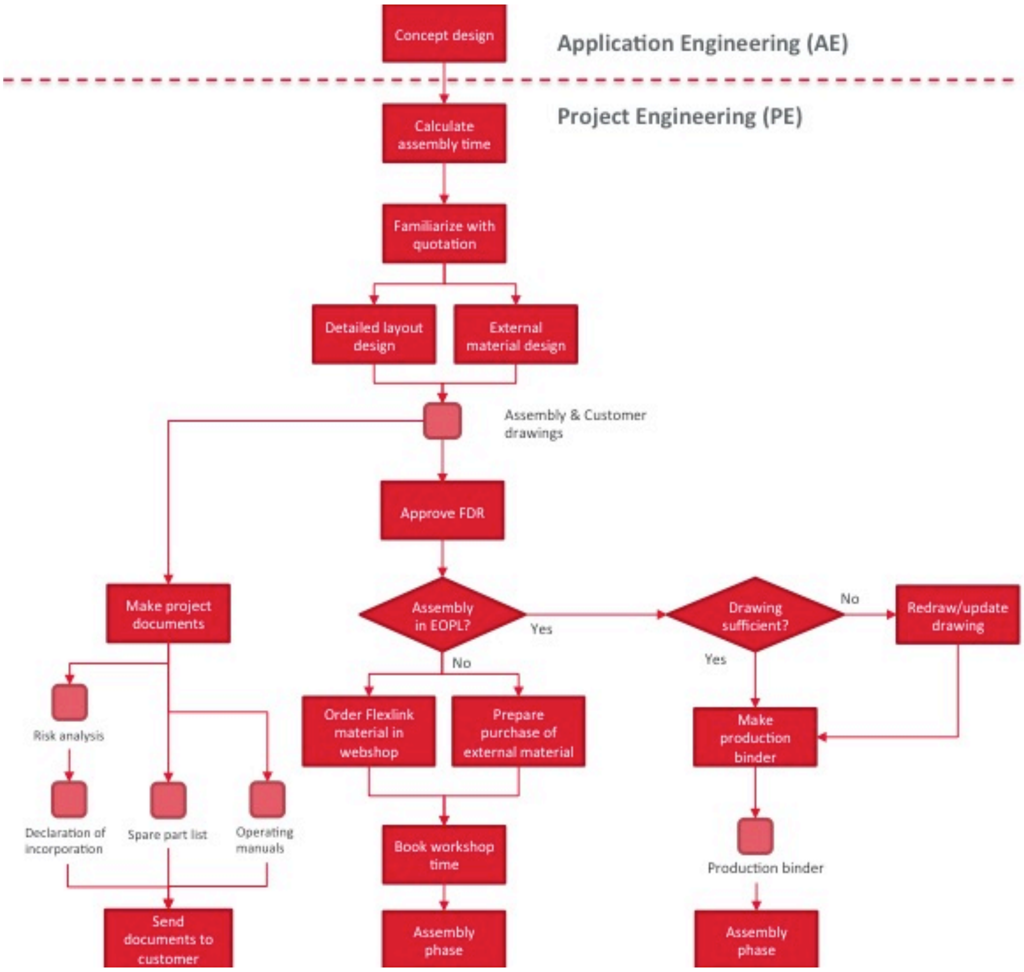

Figure 12 Project Engineering process

At first, the concept design is received and the needed assembly time is calculated. Thereafter, the quotation and customer specific requirements are being familiarized with. When the engineer has gone into detail of the specification the final design work starts. The internal parts and the external material that has to be purchased from external suppliers are put together in a CAD model. Then a decision is made whether or not to assemble the project at the designing unit or not. It could be outsourced to Poland if it is best suited for the moment in terms of occupancy and availability in the assembly workshop. If it is sent to Poland, a decision is made whether or not the drawing is sufficient or not to be assembled. If yes, the Production Binder, including all the documents to assembly, is prepared and sent to assembly and the physical completion of the project can start.

4.2.3.2 Interaction between different units

In figure 13, an overview in the shape of a Spaghetti diagram is shown. It visualize the interactions between the operating units and in the study and their connection to the spare part company PSD.

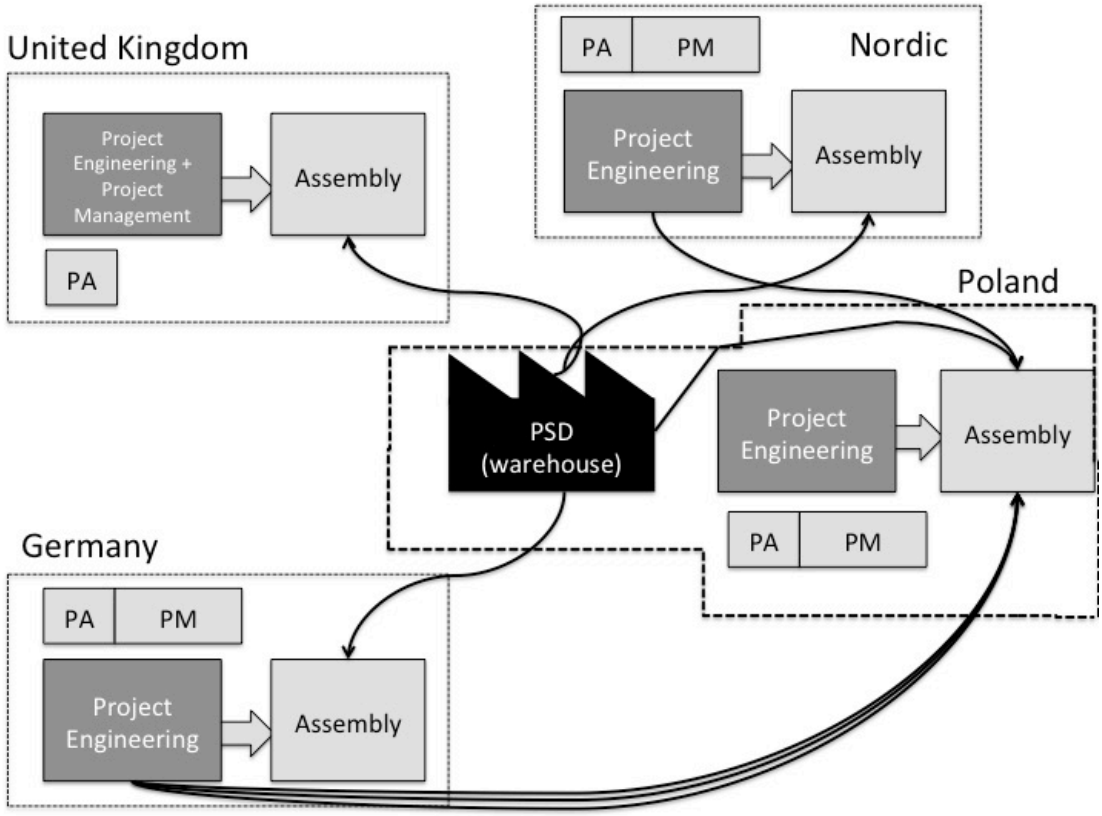

Figure 13 Spaghetti chart illustrating the interactions between the units.

The diagram was developed after interviews were held and visits were made at the different units. As seen, Poland has a lot of interaction with since both the biggest assembly workshop is located there and the main warehouse of material. The assembly workshop in Poland is used as cover up support when it is considered advantageously to outsource in terms of economy or occupancy. The recovery rate is lower in Poland, however the freight cost will be added if the project is assembled in Poland since the transport of a finished project requires larger items. However, the material are transported, to every project in Europe, from the central ware house but requires smaller items and allows a higher filling ratio.

This exchange of projects is internally invoiced and the cost is calculated by using locally recovery rates. Today, Germany is the biggest internal customer to Poland and corresponds to around 70% of their total internal customers. Sweden is the second largest internal customer to Poland and besides from Germany and Sweden. One company goal is to enable this exchange of projects between all different units, which today is hard or at some units almost never occurs. UK for example does very seldom outsource the production of their projects but it may happen their Project Engineers are hired as internal consultants, and support some projects in for example Spain. The distribution of internal customers to Poland can be seen in the Pareto graph in appendix IV.

4.2.4 Output

The output generated from the Engineering process is an approved detailed drawing and the bill of material (BOM) of the conveyor solution. The rest of the output is all project related documentation; safety manuals, customer drawings, spare part lists, instructions etc. Company idea is to have a drawing and handover documentation from Engineering to Assembly detailed enough for the assembly workers so that they do not need to comeback with questions to the engineer. The level of details on the drawing may very among the units.
In the UK unit, it was noticed when visiting, that they need a lower amount of details in the hand-over since it is a small unit with skilled and experienced engineers and a facility that enables intense level of communication between engineers and assembly workers. While in Poland the assembly workshop has a much higher turnover of staff and less possibility to communication after the hand-over.

4.2.5 Customer

Assembly serves as an internal customer and transmits the output of the Engineering process. The project sponsor; Area Director Europe Central and the rest of the management team can be seen as a customer of this certain projects since the it will according to its predicted financial model generate organizational savings of reduced administration hours. The engineers is also seen as a type of customer since the objective of the project since they may receive a changed work situation after improvement workarounds has been made.

If the project is not sent to Poland for assembly and instead completed at the designing unit, the workshop time is booked at the local unit and the physical completion of the project takes place there. The external material are then ordered from external suppliers and the internal material are ordered from the Parts and Supply Division (PSD), the central warehouse located in Poland. The Project Purchase department handles the ordering of the external material and the internal material is ordered through an internatl company web shop. Customer documentation is prepared in parallel with the completion of the project.

This is the general workflow at the four different units even though some local deviations may occur. In parallel with these steps performed by the engineer, there is also a Project Manager that owns the deliverable of the projects and a Project Administrator activating the project in the ERP system.

4.3 Current measurement system - project time

The PE department uses a global company framework of how to report project time, called FUTAC, provided by finance and central management. The framework of time codes to aimed for the engineering department can be seen in figure 14.

Productive Time	All time spent on customer or warranty projects.	Project related time	Normal working time	Overtime 1,5x (Optional)	Overtime 2x (Optional)
Non-Productive Time	All time spent on issue not directly related to any project, but necessary to carry out the daily job, or cannot be avoided.	Sales support	TSS10	TSS12	TSS14
		Innovation	TIN10	TIN12	TIN14
		Maintenance	TMC10	TMC12	TMC14
		Obstructions	TOB10	TOB12	TOB14
		Administration	TAD10	TAD12	TAD14
		Education	TED10	TED12	TED14
		Meeting	TMT10	TMT12	TMT14
		Logistics	TLG10	TLG12	TLG14
		Quality	TQU10	TQU12	TQU14
		Leadership	TLE10	TLE12	TLE14
		Other	TON10	OTN12	TON14
Absence	All time that is not spent by work.	Mandatory Paid Leave	UMP10		
		Vacation	UVA10		
		Sick Leave	USL10		
		Family Care	UFC10		
		Work Accident	UAC10		
		Time off without pay	UNP10		
		Other	UOA10		
Engineering Mechanical	7991	Engineering Normal	**E10**		
		Engineering Overtime (optional)	E12		
		Travel time	E40		

Figure 14 FUTAC codes used to report time

Every hour spent on engineering projects should be reported as *Engineering mechanical,* i.e. the E10, E12 or E40 codes should be used. This time will be paid by the customer, and are included in the price of the product. These hours are allocated to the project after being estimated by the Sales and AE department and approved by the Financial department. However, the time not spent on project work, should also be reported. There are two main categories of time not spent on projects, the *non-productive time* which can be considered operable and *absence* which includes for example sick leave, and parental leave and are not considered possible to have an impact on.

The customer does not pay for the *non-productive time* nor the *absence time.* Instead, the hours outside the projects end up as S&A costs and will affect both the Recovery rate and the EBIT results of the company as can be seen in figure 3. However, a company standard way of reporting time does not, as previously mentioned, work in the exact same way. There are different prerequisites at the different units, since the work in different ways and have local KPIs, and other perceptions on what to achieve.

4.4 Financial baseline

In figure 15 a compilation of the project costs for all the European units of 2015 is shown. A potential elimination of 10% of the admin hours at the European units would enable savings of 222 k€ a year with the current average efficiency rate of 75% for European projects.

Country	Recovery Rate	Eng/PM Cost EUR	Eng/PM hours/0,75	Admin hours	10% of Admin hours	Cost of 10 % admin hours (potential savings)	Possible extra revenue for freed up hours	Sales/ Hours
Belgium	70 €	-180 648	3 441	860	86	6 022	62 466	726
Czech Rep.	30 €	0	0	0	0	0	0	0
France	67 €	-329 120	6 550	1 637	164	10 971	130 525	797
Germany	85 €	-1 840 563	28 872	7 218	722	61 352	624 356	865
Hungary	35 €	-59 001	2 274	568	57	1 967	28 157	495
Italy	52 €	-974 836	24 996	6 249	625	32 495	227 493	364
Netherlands	65 €	0	0	0	0	0	0	0
Nordic/Sweden	81 €	-1 599 653	26 481	6 620	662	53 322	271 358	410
Poland	37 €	-1 069 487	38 347	9 587	959	35 650	521 837	544
Spain	52 €	-385 866	9 990	2 498	250	12 862	183 712	736
UK	85 €	-232 217	3 662	916	92	7 741	97 114	1 061
	60 €	-6 671 390	144 612	36 153	3 615	222 380	2 147 019	594

Figure 15 The financial model of the project

Furthermore, if those freed up hours could be used on engineering projects instead, it would make room for an increased revenue of 2 147 k€, according to the company's sales per engineering hour ratio of 2015. This financial model was shown for management in the beginning of the project as an example of savings that could potentially be achieved by the project.

4.5 Analysis of existing data

In the sections below the time data from the PE departments at the different operating units, are represented in Pareto charts. The data is received from the Financial department at the head quarter in Gothenburg. It was thereafter sorted and visualized with Pareto charts in Minitab. On the y-axis in the figures, the annual amounts of hours for each Project Engineering department are shown. On the x-axis each bar corresponds to each different FUTAC labor code that has been reported. From July 2015, the codes shown in figure 14 should according to the new FUTAC be used. Before then, there was no common strategy for the whole organization of which codes to use.

4.5.1 FlexLink Nordic

In figure 16, 98% of the reported FUTAC codes at the PE department of the Nordic operating unit from 2016 are presented. As seen, there are no T-codes reported. It means only project hours are reported. The other not reported time, becomes uncategorized non-productive hours and ends up as S&A costs on the EBIT results.

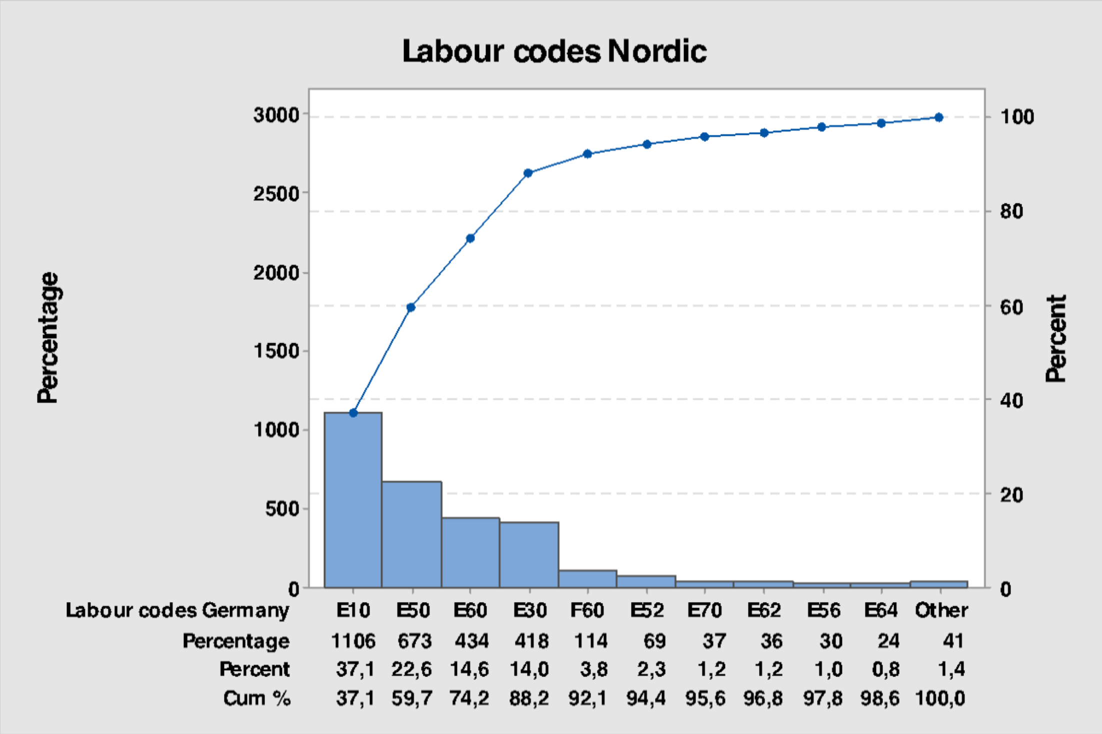

Figure 16 Reported FUTAC codes of the PE department - Nordic unit 2016

Project Engineers and Project Managers at the Nordic unit were asked how they reported their non-productive time. It was found that different views upon how to report existed. What was in common was that nearly all time was either registered as project time or not registered at all and hence becomes S&A costs. A few exceptions exist, e.g. company meetings and training that most seem to report as categorized non-project time.

4.5.2 FlexLink Poland

The FUTAC codes for the PE department in Poland in 2015, are visualized in figure 17. The polish was using their own local T-codes extensively. The standard codes were alse used but not to the same extent. T890 and T200 are examples of the local T-codes only used at the Polish unit. In addition to the local T-codes, there are also different codes for Engineering work compared to the other units and the standard. In Poland C-codes are used to report project work. Which in fact complicates the analysis and comparison of the different operating units.

Th five most reported T-codes corresponding for 45% of the total time reported in 2015, are all Sales, meeting and administration related. This indicates a high amount Administration of the unit. It was noticed after further investigation that the all Project Managers time is automatically reported as 50% project time and the remaining 50% as Sales and Administration costs. This due to a KPI that by the end of each year should have that distribution, even if the proportions look different in reality. Poland is by far the biggest unit with almost 34000 engineering hours in 2016.

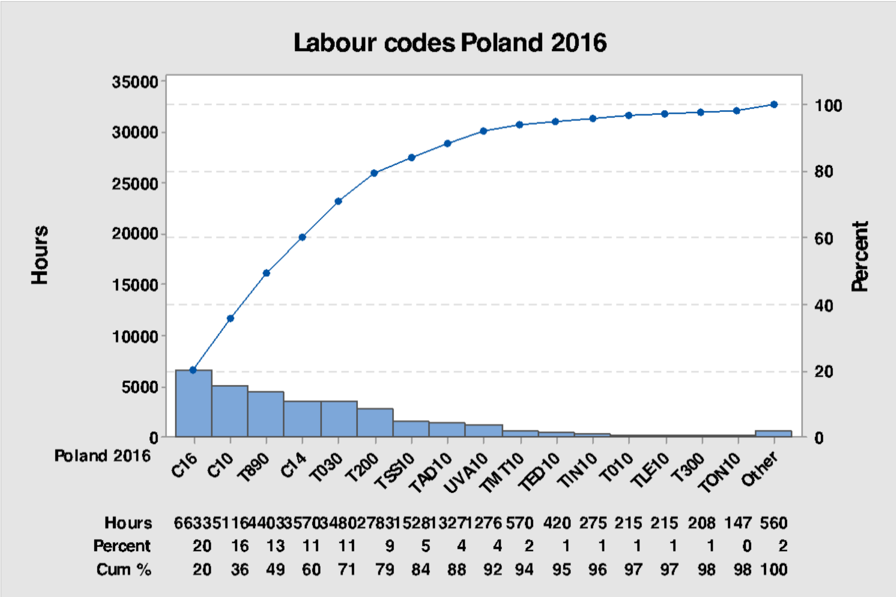

Figure 17 Reported FUTAC codes of the PE department - Polish unit 2016

4.5.3 United Kingdom

UK is a small unit with around 1200 Engineering hours for 2016, compared to Polands 34000 the same year. The two only engineers acts as both Project Engineers and Project Managers in a combined role. The code PMGT is highly represented and is a local code for project work. The distribution for 2016 can be seen in figure 18. The category *TON10* represents is defined as *Other* and could consist of different tasks not considered as project work. The second most represented T-code is *TSS10, Sales Support* which is also a part of the combined PE and PM role. When further asking the engineers in UK unit about their positions, they describe themselves as *wearing different hats* and sometimes act as salesmen, robot programmers and customer support.

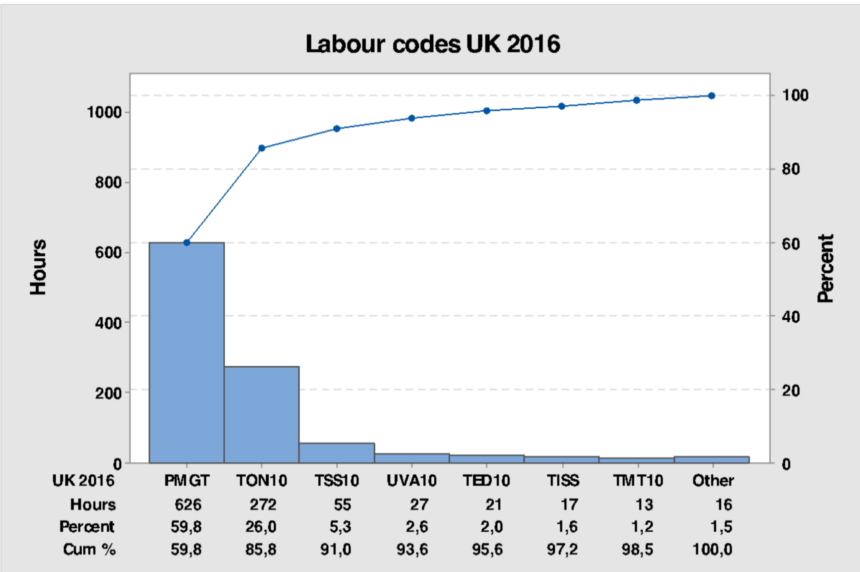

Figure 18 Reported FUTAC codes of the PE department - UK unit 2016

4.5.4 Germany

As seen in figure 19 the ENG, P10 and CE10 codes are the most represented. These are the project codes for mechanical engineers, project mangers and electrical engineers. Hence the customer pays that time. The most represented T-codes are TAD10 (administration), TSS10 (sales support), TMT10 (meeting) and TED30 (training). It was noticed that the FUTAC reporting system seems to be used by all employees at the German unit by the year of 2016. Despite that a low amount of T-codes existed.

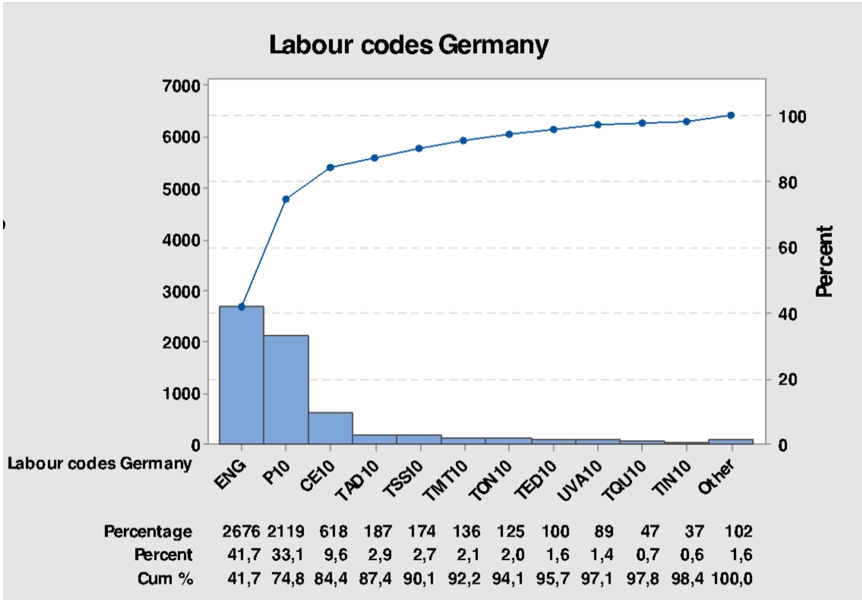

Figure 19 Reported FUTAC codes of the PE department - German unit 2016

4.6 Measurement System Analysis

After evaluating the time reporting system and the different reported categories of time. The system is considered to be trustworthy to the extent that the total amount of reported project time is correct. The total amount of non-productive time is also considered to be correct. However, the categorization of the reported non-value added time differs between the units. Sweden for example, does not categorize the non-value added time at all. Another example of differentiation is the reporting of the Project Managers time. In Poland 50% of their time is automatically allocated to projects and the rest as administration costs. This regardless how the distribution looks in practice.

The conclusion of the measurement system analysis is that it is reliable enough to use for the financial department in order to set efficiency rates when budgeting, but not accurate enough to use for further analysis of the non-productive time. The project margins are also possible to manipulate if reporting more or less time on projects than is spent in reality. Conclusion is that new data needs to be collected in the same way at all units, so that it is can be overviewed and lumped together and not just analyzed each unit one at the time.

4.7 Visits at units

All the units in the study except Germany have been visited throughout the project. The visits were done in order to see the process firsthand and investigate to which extent it is adapted locally at each unit. Furthermore interviews were held with Project Engineers, Project Managers and Project Administrators in order to gain better knowledge of the current state for the forthcoming data collection.

4.7.1 Interviews

In total 16 interviews were held throughout the Define phase at the different units. The interviewees were asked which top of mind issues they hade in their daily work. They were first asked to speak freely about which top-of-mind issues they had that interrupted and disturbed their daily work and could be seen as non-value added. Thereafter a few standard questions were asked in order to see if there were correlations with issues occurring at the other units. The main purpose with the interviews was for the researcher to get familiar with the current state of the process and try to identify some noise factors disturbing the process.

Project Management Poland

Both the Project Manager and the Project Administrator expressed dissatisfaction about the many different IT tools to use. Examples of tools are Skalmex (locally developed project management tool), Movex (ERP system) and locally developed Spreadsheets and Google documents. The communication with other units, when Engineering projects are outsourced to Poland, was also highlighted as problematic. However, the contact with Germany is described as more easy to manage because a communication form in shape a document developed for the contact between Germany and Poland. The Project Manager also mentioned that they sometimes have more work at the Polish unit than they are manned for, and that the difference in workload goes in cycles.

Project Engineering Poland

The Project Engineer in Poland described the daily work situation as smooth in general with few interruptions and non-value added tasks. One annoying thing on top of mind by the engineer was the amount of questions that came from assembly, after the drawings and the project documentation had been handed over. It was described as human mistakes. Which according to the engineer was an unavoidable and unpredictable errors that may appear either due to faults by Engineering or Assembly. The engineer also mentions the contact with the German Engineering unit to be certain good. The Engineer said that mainly Inventor is used to make Assembly drawings. If the drawing is of another format than Inventor, e.g. if another operating unit or AE is using AutoCAD or FLDT, then the project will be redrawn in Inventor by the Polish engineers. Those extra hours are either invoiced internally to the other operating unit or paid by the customer.

Project Administration Poland

The Project Administrator in Poland contributed with input of daily non-value added tasks connected to Engineering projects. The opening of a new project and activating it in the ERP system contains a lot of manual load of data into the ERP system (Movex). Post-its or notes must be made manually from a email transmitted from Application Engineering containing project information, due to no possibility to copy paste all the fields twice. The Production Binder, which is all the documentation including drawings and material lists, that is transmitted by the assembly contains a lot of printing and manual work. The Production Binder also requires to sort all the drawings in the right order. Skalmex, the locally developed project management tool, once crashed and project data for two months got lost which caused major problems.

Manu of the projects that are outsourced to Poland from another unit sometimes have incomplete or not fully finished part lists. This causes extra administration work in form of phone or email contact with the Project Engineer in order to get all the documents needed.

Project Management Nordic
A lot of time for Project Managers in Sweden is spent on time reporting. There is no connection between the two systems Etimes, the time reporting system and Agda, the salary software. It means the data of engineering hours has to be manually transferred between these tools. Questions from the assembly workers also occurs and they could be of different kind, either due to engineering mistakes or due to a deliberately not detailed handover of drawings, made less detailed in order to save engineering hours. No standardized layout and detail level of the drawings to handover to Assembly exists. The handover between AE and PE sometimes also lacks information and the engineers need to go back to AE with questions.

Project Engineering Nordic
Today there is no standardized way to store and save old projects, it means a lot of knowledge gets buried and it takes a lot time to search for previously invented solutions. All Engineering projects are saved in a local folder library where all the engineers had created their own structure of old projects. This structure makes it more difficult to reuse previously knowledge gained in old projects. I means the engineers sometime have to "reinvent the wheel" and spend non-value added time on redesigning an already existing design.

Second major issue according to the Nordic Engineering department was that other units use different CAD libraries for standard files. It means the standard components; screws, conveyors, brackets etc., are saved to another desk. This means the CAD file of the project will be imported as an STP file, i.e. one single "dead" component with no dimensions or separated parts. This can lead to need for re-drawing and in worst case; need to make new measurements of dimensions at customer's site.

Project Administration Nordic
Opening up projects in the ERP system was described as the major issue and non-value added activity for Project Administration at the Nordic unit. The problem is described in the same way as by Project Administration in Poland; *"a lot of manual load of data between emails, spreadsheets and Movex the ERP system".* Another mentioned issue are the emails transmitted from the Sales or Application department containing project information. They are sometimes incomplete of information, which may delay the start of a project.

Moreover there is no connection between the tool used for quotations where sales and customer info are given and Movex, the ERP system. This means quotation data needs to be transferred manually between these two tools. The allocation of a Project Manager can also be delayed.

Project Management and Project Engingeering UK
Because of the small size of the unit in UK, relatively the other operating units, the two engineers work in combined roles as both Project Mangers and Project Engineers. A lot of time is spent on expert guidance and discussions with the Sales and Application Engineers. According to them it is a result of being a small unit, which makes it possible for them to share their knowledge easily in order to propose the right layout of the solution at an early stage. The same type of discussions and meetings are held with the assembly workers, preventively, before the assembly has started. The engineers used the analogy they are "wearing different hats" it means acting in different roles and share their knowledge wherever it is need. Therefore these types of meetings and discussions are seen as value-added and a part of the units mentality.

However, some problems were mentioned; one is that AutoCAD crashes a few times a week. Inventor is used very seldom. The use of AutoCAD prevents the possibility to exchange projects with most other units, the engineer does not see this as a problem since that type of cooperation and internal trade of projects with other units occurs very seldom. If there is some interaction with other operating units it is with those few that use AutoCAD.

The only interaction the UK unit have with Poland is when they order material from PSD. Ordering material from PSD is sometimes perceived as problematic, mostly due to change of delivery dates that occurs sporadically. This makes it harder to plan for start and finish dates of projects. Project number and part numbers must also be filled out many times throughout the project in various tools and word documents, which is time consuming. Customer documentation is burned on a CD, which also takes non-value added waiting time.

Project Administration UK
In the same manner as the Nordic and Polish unts the sequence of opening up projects in Movex is described to be complex and time consuming. To prefer would be one system that integrates the quotation tool used by AE and hence skip the loading of data manually into Movex. A few other detailed problems directly related to Movex were also addressed by the Project Administrator.

The role of a Project Administrator in UK differs remarkably between the other units, again due to the small size of the unit. The role of the administrator also include, purchasing, facility management and telephone exchange to the rest of the unit. Approximately 40% of the time is spent on Engineering projects.

Project Administration and Engineering Manager Germany
Throughout the project there was not time enough to visit the German unit. However video interviews where held with the manager of the Engineering department and with one of the Project Administrators.

The heavy workload was a major issue according to the Project Administrator, as well as the many different electronic tools to use. External purchase orders results in a lot of manual work of manually checking part and project numbers and prices. Ordering engineering or assembly hours from EOPL, the Polish unit, is not well working process. The hours must be booked as material instead of hours, which causes problems.

4.7.2 Summery of interviews

Several top of mind issues was identified throughout the interviews. However, it is likely to believe that there are many more non-value added moments that might be hard to remember during an interview. Therefore in the measure phase more data was collected. Below the identified main categories of problems identified throughout the interviews are presented.

ERP system and local IT tools
Many of the findings of non-value added activities were related to Movex; opening of projects, integration of quotation tool, problems when ordering material etc. However, Movex will be replaced by SAP within a period of two years and there is another ongoing project managing the transformation into the new system. Therefore all the issues related to Movex will be handed over to the SAP project and left it outside the scope of this project. Some locally developed project management tools are used, an example is Skalmex in Poland. It requires some manual work and contains a lot of information and has no connection to Movex.

Assembly issues
Assembly problems occur at all units and results in questions to the engineers that interrupt the actual engineering work and might also delay the Assembly's finishing of the project. In UK this type of questions is not necessarily seen as noise factors but instead seen a part of their standard way of working, since both the engineers and assembly workers are experienced and skilled and does not require long discussions to untangle the eventual issues. The UK unit is a small unit, which is geographically isolated with low interaction with other units. This has created their own ways of working. However, in Poland, Nordic and Germany this type of assembly issues should not arise if the process worked as planned.

Handover - Engineering to Assembly
The documentation handed over from PE to Assembly differs a lot between the units. Poland and Germany are using a "production binder" with all part lists and drawings printed. In UK the handover consist mainly of a dialogue with the assembly workers before the project start the top assembly drawing, i.e. the overview drawing of the project.

Handover – Application to Engineering
This handover will be accurately investigated by another ongoing project carried out by the manager of the Engineering process at the Nordic unit. For that sense it has been left outside in this project

Different CAD programs
Use of different CAD programs is also a problem. The use of different CAD libraries for standard files will expire. All units will start to use FlexCad a common desk for all the files. The use of three different CAD tools also causes conflicts when transferring files. FlexLink Design Tool (FLDT) that is mainly used for smaller projects in the Nordic unit. Inventor is used for larger and more complex projects. Poland are almost exclusively using Inventor while UK use AutoCAD. When exchanging projects between the units using different CAD programs, it often leads to need for re-drawing of the whole CAD model. This especially occurs in Poland since they assemble and design many projects transmitted from other units.

Lack of structure – finished projects
There is no structured way to store old projects, in Sweden for example the engineers saves the project in own developed folder structures on a local desk in Sweden. However a global PLM system called ARAS are under development and are planned to be implemented in 2017. This could mitigate the risk of burying knowledge when not finding old smart designs easy. Therefore this issue will not be further analyzed by this project.

4.8 Identified big Y

The identified capital Y of the process are after the visits and interviews and by the end of the Define phase defined as ”Administration costs for projects”. Which concerns the number of non-value-added hours throughout the Engineering process. However, it has been concluded it is not the same thing as the non-productive hours reported by the personnel, since there are differing perceptions of what should be reported as non-productive or not among the operating units. Therefore new data is needed with a clearly communicated definition of which time that is considered non-value added. This in order to overcome old habits and beliefs of what is value-added or not. The identified bug Y is visualized in figure 20.

Figure 20 Project’s big Y

5. Measure

The aim of the Measure phase in Lean Six Sigma is to identify key inputs and outputs of the process and to develop a plan for data collection and to collect the data (George et. al, 2005). Some data, from the interviews and existing baseline data, has already been collected and analyzed in the Define phase. Therefore the Measure phase has been focused on the collection of new data. It has been carried out using a survey. The steps of designing and carrying through the survey data collection will be described in the sections below.

5.1 Data collection design

After the interviews were held, some main categories where non-value added activities frequently occurred were chosen to be included in the survey. These new categories together with existing time reporting data were combined into twelve new categories. A reduced view of the survey can be seen in figure 21 with not all the categories represented.

	Non-project-time	Administration (project related)		Data transfer (between tools)		Assembly		Meeting		Supply Chain problems		Comments & lack of category
		No. of times	total (min)	No. of times	total (min)	No. of times	total (min)	No. of times	total (min)	No. of times	total (min)	
Week 46	16-11-07											
	16-11-08											
	16-11-09											
	16-11-10											
	16-11-11											
Week 47	16-11-14											
	16-11-15											
	16-11-16											
	16-11-17											
	16-11-18											
Week 48	16-11-21											
	16-11-22											
	16-11-23											
	16-11-24											
	16-11-25											
Week 49	16-11-28											
	16-11-29											
	16-11-30											
	16-12-01											
	16-12-02											

Figure 21 The layout of the survey showing five of the categories

A pilot study of the survey was performed during one week. It was attended by one Project Engineer at the Nordic unit. The pilot study was performed in order to investigate if the thought off categories in the survey were adequate and if there were any misconceptions in how to fill it out. One important finding from the pilot study was that it was easily confused with the regular time reporting. Hence there was a risk of getting just being a copy of existing time reporting data. Which was condemned as non-valid already in the Define phase. Therefore the time and activities to be filled out by the attendants was defined and formulated as:

"Logg any time consuming task within and around engineering projects that could either be eliminated or improved."

A few other adjustments of the design were made after feedback from the pilot study in order to make it more intuitive and avoid misconceptions when sending it out.

The participants of the Survey were designated by local management at each unit. Ever since the first contact was taken with the participants it was clearly communicated the only mission with the survey was to collect information in order to improve the process. Hence enable the organization to grow and reach the company goal of 100% increase in sales within the next five years. In total there were 23 participants from the four different units filling out the survey. The participants were; Project Engineers, Project Managers and Project Administrators. The total population, at all the units of FlexLink in Europe, of these categories amounted of 82 employees. Hence the sample was considered to be representative enough.

The survey was a combination of a time log and a diary. For every non-value added activity that occurred, the participants were instructed to fill out how many times (frequency) this activity occurred and how long time each occasion took. Inn addition to the time log they were instructed to add an explaining comment to each non-value-added occurrence in order to propose more information about its causes. An instruction was sent out and two video meetings were held, one with management at each site and one meeting for all participants. The survey was shown for the participants and they hade the opportunity to leave feedback before the final version was sent out. The participants were also asked to send in the result weekly and not just in one shot after four weeks, in order to see that no misinterpretations seemed to occur.

6. Analyze

The main purpose of the Analyze phase of the DMAIC process is to find critical inputs, called x-factors, that are causing the unwanted variation of the process (George et. al, 2005). Further also to prioritize the most important factors to focus on. The data collected in the Measure phase will be analyzed together with the data from the findings from the interviews and the observations in the Define phase. The idea is to identify the x-factors and try to either make them controllable or eliminate them. Below the carrying through of the Analyze phase and all it's outcomes.

6.1 Result survey

The response ratio of the survey was 19 out of 23 participants, i.e. 83%. Some of the participants were more engaged than others and gave feedback and continuously sent in the results throughout the period. Some participants seem to have misinterpreted the concept and had filled out their fulltime in the different categories of non-value-added time, which implies the data is invalid. These deviants of two participants were therefore removed from the result. It was considered to have insignificant impact on the result, since they were all located at the Polish unit that had, a solid number of participants even after (9 instead of 11). Below the quantitative result, the amount of time reported on non-value added activities, and the qualitative result from the comments field will be presented. The qualitative data, the comments, were not added to the survey by all the participants. More comments would have made the qualitative root cause analysis more profound. In retrospect, more advantageously could have been to design the survey with a primarily focus on the comments, to lead more focus into the comments. It may had led to less confusion with the survey and the time reporting.

6.2 Quantitative data – survey result

The result was compiled in to one sheet and Pareto diagram of all the categories was generated. In the figure 22 the result of all the engineers only is presented. This since the Project Manager and Project Administrator roles largely by nature consists of administrative tasks. However, the result of all the participants, the full sample, has also been analyzed and no significant difference was found except some higher representation of the Administration category. The quantitative result of all participants can be seen in Appendix V.

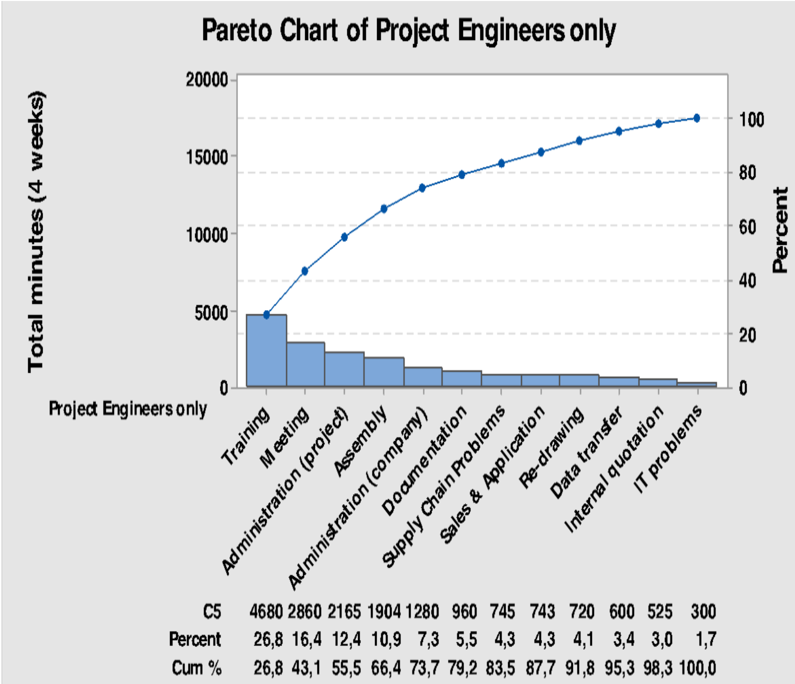

Figure 22 Pareto chart of the quantitative result of the survey

The high representation of the *Training* category can be seen as a consequence of the relatively short survey period of four weeks. If a few engineers are away for some days of full time training, it remarkably affects the result. The training itself is in the end also value-added for the company, since the knowledge among the engineers will be strengthened.

The second most occurring category, *Meeting* (16,4%) consists of a large amount of customer meetings, which are seen as value-added and therefore not focused on. The other meetings are department meetings and meetings with the assembly. Department meetings are not considered possible to have an impact on for this project. Assembly meetings, as previously mentioned, are a natural part of the UK standard way of working but normally not in Poland or Germany.

Project related administration, the third largest category from the quantitative result is a bit more diverse and hard to categorize. It seems like it has been used as a rest category when no other is category fully suitable for the certain issue. This category is therefore considered difficult to split up and to categorize.

Assembly, the fourth largest category was predicted after the interviews and visits were made. The remaining larger categories were *Documentation*, where most of the result could be connected to Poland and their customer documentation. It can be seen as time consuming but still value adding for if that is what the customer requires. Re-drawing was expected to be more from what was heard throughout the interviews, it gained 4,3% of the total.

The Pareto diagrams of the quantitative data give an indication of which issues that are most represented. However, it does not dig deeper into root causes and the reasons behind the occurrence of the problems and how it is connected to the process. Therefore the qualitative analysis were performed.

6.3 Qualitative result - diary data

In order to analyze all the comments connected to the highlighted issues in the survey, an affinity analysis was made. It was done in order to see if there were any correlations of the experienced problems, between the different units. More than 100 comments was written on post-its, sorted into the right categories and then grouped together into common themes. A picture of the affinity analysis can be seen in figure 23. Different colors indicate different units.

Figure 23 Picture of the affinity analysis

Many of the comments were formulated in a general and not so detailed way. However, it was possible to group and circle some of the issues into sub-groups of the 12 categories. Many comments where "stand alones", which means they might not be connected to another occurring issue. Examples of such issues was are *"Mouse broke down, needed to get a new one"* or *"wrong calculations made in one quoute, needed to be re-done".*

Assembly
One large area that was, according the sponsor and the project team, possible to have an impact on was the problems related to the Assembly. A common theme of these post-its were identified; they are all problems occurring in assembly and the engineers needed to spend time. Despite the project had already been handed over project instead of working on the current ongoing project. This area was decided to focus more on. As concluded already throughout the interviews, the handover documentation transmitted by assembly differs remarkably between the units. Remarkable were the high representation of assembly issues that seem to occur in Poland and Germany, despite having a detailed and massive handover of documents in for of the Production Binders.

Re-Drawing and different CAD tools
The category of re-drawing had lower representation than expected, since a remarkable occurrence was observed during the visits and interviews. Especially in Poland and the projects designed at a different operating unit and then outsourced to Poland for Assembly. Investigation showed that the hours spent on re-drawing was invoiced as engineering hours and therefore got paid for. This means that this re-work was not seen as double work but instead as just standard work.

In order to get information about how many projects that had been re-drawn in Poland, more data was requested. All projects in Poland between September and December 2016 were investigated. 17.1% of the projects had more than one Inventor drawing, either an extra FLDT drawing or an extra AutoCAD drawing. Since there is not possible to export drawings and models between these different CAD tools it means these 17.1% of all the projects needed to be re-drawn and double work occurred.

One conclusion drawn from this is that the use of different CAD tools generates re-construction and re-drawing of the projects. Which is double work and hence is non-value added. This type of re-work seemed to be a symptom of the lack of connection between the different CAD tools. Therefore a meeting was set up with the Engineering Tools department at the headquarter in Gothenburg. Engineering Tools is a central unit that maintains and develops the CAD tools that are used at the company. It showed out a new function would be released in 2017 enabling the export of a CAD model and drawings between FLDT and Inventor. This means the re-drawing caused by conflicts between Inventor and FLDT could be replaced by instead exporting the whole CAD model between the programs. All the parts and dimensions would be intact.

One additional finding from the meeting with the Engineering Tool department was that AutoCAD is less and less supported and maintained. The new global CAD library FlexCAD, is not compatible with AutoCAD, it means locally stored CAD libraries must be used for those units that are using AutoCAD. According to the Project Engineers in UK, AutoCAD crashes sporadically when designing large projects. One possible reason according to the engineers are that AutoCAD is not aimed for larger 3D projects and the graphics gets to heavy for the program, which results in breakdown and risk of losing information.

Additional findings - affinity analysis
Data transfer between tools could be time consuming, e.g. when exporting a CAD file to an STP file. However, STP files are only used if the customer requests for such a format. In that sense it could be seen as value added. A lot of comments addressed waiting of exporting a file to another CAD library e.g. Vault instead of FlexCAD. Since FlexCAD will become a global standard CAD library, this will not be problem in the future if the new company standard is followed.

Some various individual IT issues also exists, but no pattern of causes could be identified. The preparation of customer documentation could also be time consuming. However, this is left out of this project since the other parallel ongoing thesis project is more focused on that particular documentation process, and possibilities of making it more efficient. Time reporting seemed to be time consuming but no long intervals at the time, and the new ERP system (SAP) might also bring a new function for this. The fact that the time reporting procedure is seen as complicated and time consuming may have affected the poor quality of the existing FUTAC data, seen in the Define phase.

6.5 Waste analysis

The Lean Six Sigmas 8 categories of waste analysis called TIM WOODS (iSixSigma, 2017) was performed in order to categorize the findings of non-value added activities and waste throughout the process and to see that nothing had been overlooked. The analysis is based on the findings from the survey, visits and interviews made. Some of the findings are shared with the other ongoing thesis project (Larsson & Sadriu, 2017).

Overproduction: No overproduction seems to occur in the Engineering phase since all the projects are developed on demand of a customer.
Inventory: Project documentation might be in shape of hard copies that are stored as backup in binders.
Waiting: Waiting for documents to be approved, waiting time when outsourcing projects to other units, waiting when uploading documents to WeShare/burning to CD (UK), waiting for production binder to be ready for assembly (Poland), waiting for dedication of Project Manager (Nordic), waiting to get information from AE to kickoff project.
Motion: Moving around to ask questions in order to prepare the Production binder (Poland) and going to the assembly workshop when problems occur.
Transportation: Production binder (EOPL) needs to be physically transported and signed by six persons.
Defects: Re-drawing of CAD models when making Inventor models of FLDT models, Conflicts when using different CAD file libraries (Vault/Flexcad). Problems in workshop that engineers have to solve, AutoCAD sometimes crashes. However, making the same drawing twice not necessarily seen as re-work among engineers.
Over processing: Risk of putting too much information on drawings, All units developed their own processes and tools, it leads to cost of maintaining, Many tools to use; Excel sheets, Movex, Scalmex etc.
Skills: Ideas buried in an unstructured folder system of saved projects. However, will be replaced by new PLM system.

6.6 Conclusions - Analysis phases

It is concluded the occurrence of non-value added activities exists also within the engineering hours, and not just those being reported as non-productive time in the time reporting. Some focus of the project focus was therefore needed to change. The new focus can be seen in figure 24. This new perspective means that engineering hours could be freed up also among the invoiced hours. This with purpose to make the whole engineering process more efficient rather than just cutting costs in order to enable an increased amount of projects and an increase in sales. To categorize the non-productive hours as the only hours to be non-value added is therefore concluded to be misleading.

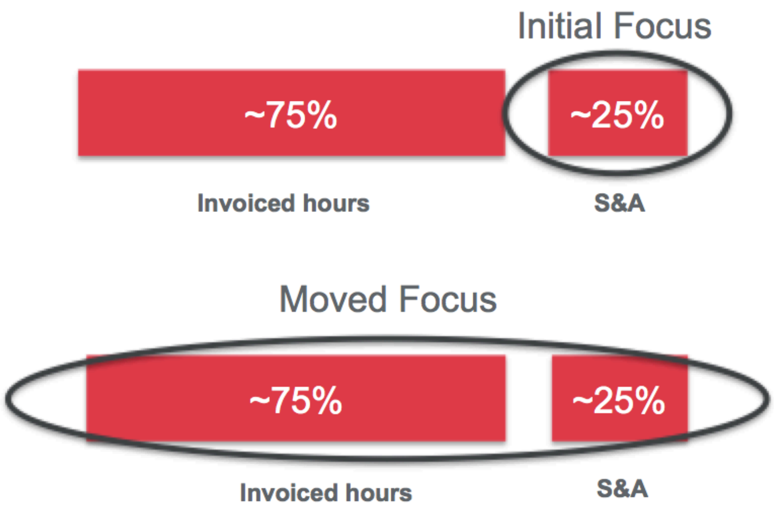

Figure 24 Distribution of project hours and switch of focus

6.7 Identified x-factors

Based on the findings from the survey, interviews and observations the critical x-factors of the process to put focus on have been identified. The chosen x-factors are.

- ***X1 = Different (CAD) tools used,*** the use of AutoCAD, Inventor and FLDT complicates the cooperation and exchange of projects between the operating units. It also costs to maintain all three and causes re-work.
- ***X2 = Re-drawing***, can be seen as a consequence of X1, however occur due to other reasons than different CAD tools, e.g . the use of different CAD libraries (Vault vs. FlexCAD) and the general perception of what re-work is among the personnel.
- ***X3= Handover assembly***, The handover of documentations and drawings to the assembly vary remarkably between the units, UK with their face-to-face meetings combined with an overview drawing and Poland Germany with their detailed production binders and Nordic unit that varies depending on the complexity of the project. There is no global standard of drawing layout used today. In order to overcome the unwanted variation of assembly problems there is a prerequisite to first ensure that adequate information is handed over.

These critical-to-quality x-factors have been chosen since they were are considered most likely for the project to have an impact on. Moreover the mitigation of these factors would create a more stable process and enable economical savings.

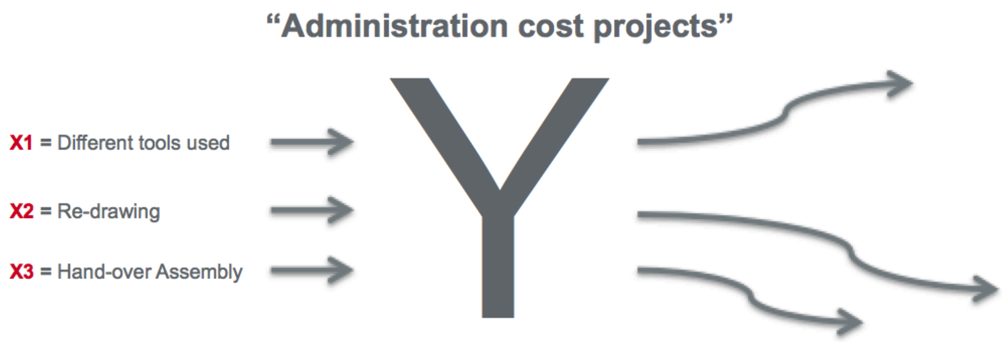

Figure 25 Illustration of the process capital Y and the identified x-factors

7. Improve

The aim of the improve phase is to evaluate and select proposed solutions based on the findings and to explain how the future state would look like with the solutions implemented (George et. al, 2005). In this section the suggested improvements are listed and connected to each x-factor. Some additional suggestions, not directly related to x-factors, will also be presented.

7.1 X1 - Use of different (CAD) tools

After has conducted meetings with both the Engineering tools department and the IT department it was concluded there will be less and less support for AutoCAD from both departments. The company standard CAD programs of FLDT and Inventor will neither be improved nor more connected against AutoCAD. It will lead to need for re-drawing when exchanging files between the different programs. The CAD libraries of standard files will also not be supported centrally from the IT department or the Engineering Tools department. There are a few units in Europe still using AutoCAD and all units in the US. No unique features exists that AutoCAD offers which cannot be replaced with FLDT or Inventor. Therefore it is considered possible to phase out AutoCAD fully and replace it with FLDT and Inventor. A phase out of AutoCAD would require a transition plan and a change management program with support from central part of the company. Training in FLDT and Inventor would also be required since some engineers may have used AutoCAD for a long time.

Possible winnings – Phase out AutoCAD & increased usage FLDT

The Engineering Tools department made an estimation of possible savings the use of FLDT instead of AutoCAD would enable. It would approximately take ¼ of the time to make an Application drawing, the first layout used for quotation, in FLDT than in AutoCAD. In 2015, 1344 quotations were made in the US. The exact time it takes to produce a general application drawing is hard to estimate since each project has a unique design. However, an approximation was made using 3-point estimation, to one hour per drawing. It would hence enable annually savings of 65 000 € if these drawings would have been made in FLDT instead.

The phase out of AutoCAD would also imply annually savings of 750 000 SEK for the Engineering tools department, since there would be no need to maintain and support the tool.

7.2 X2 – Re-drawing - improvements

Some of the re-drawing were caused by the use of different engineering tools. It could be avoided if AutoCAD is no longer used and if the export function to between FLDT and Inventor is released. The FLDT-Inventor export function is planned to be released in Q1 2017. One challenge for the company will then be to inform and convince everyone by start using the new function and not continue with old routines of re-drawing, to change the behavior among the engineers.

The other root cause for re-drawing, the conflict between the different CAD libraries and FlexCAD, would no longer occur since FlexCAD are now used as standard. However, the new standard must be clearly communicated and gained approval for by all different units around the world. It would required support from central management, that no more local variants of CAD libraries can be used since they will not be supported and conflicts may occur when exporting and exchanging files between units using the standard and those who do not. Another perquisite in order to decrease the amount of re-drawing is the general perception of the term *re-drawing* at the company. Every time a drawing is made more than once it is a non-value added activity. Even though reasons for the re-drawing may exist, it is still double work, which should be avoided since it could savings in cost and time.

7.3 X3 – Handover Assembly

Which certain documents being handed over from PE to Assembly seemed to vary between the operating units. The lack of standards of the drawings makes it difficult to know from where the problems in the assembly origins from. A prerequisite in order to run future projects investigating these assembly issues is therefore to set a standard of what to include on the drawings in terms of layout and detail level. It turned out that there was already an established standard for drawings, developed by engineers from 5 different units in in July 2016. However, this document had not been released. A meeting was set up with Project Engineers and Project Managers from Sweden, Poland, UK and Germany in order to agree upon this standard and to see if there were any supplements to add to the standard. Some different examples of drawings were shown and a discussion was held. The different requirements from the different units were collected and the standard developed in 2016 with some small configurations was decided to be implemented.

Another meeting was set up in order to go through the extensive handover of documents in Poland; the Production Binder. It was found to be the most extensive handover documentation of all investigated operating units. Some information was found to be occurring more than once. Possible future project could be a streamline of the Production Binder and see which documents that are "nice to have" and which are critical. Slimming this amount of hardcopies would save time and cost for the Project Administrator. A new project was suggested in order to investigate the possibility of having a global standard for the all handover documents, and not only the drawings.

Possible winnings – Implementing a global standard of drawings

A global drawing standard would not only give the possibility to carry out future improvement projects focused on reducing the problems occurring in assembly. It would also provide the Engineering Tools department a standard to relate to when developing new features to the software used by the engineers.

It would further also enable an extended exchange of engineering projects between the units, so that the operating units can cover up for each other when the other unit has higher occupancy than the other. In that sense it facilitates sharing of expert knowledge across the worldwide organization.

7.4 Further suggestions of improvements

In this section the suggestions of improvements not directly related to single x-factors or input variables are presented.

Time reporting system

The time reporting is considered trustworthy when it comes to the total amount of project work and non-productive time. However, the reporting and categorization of non-project time works different at different units and is not used for anything today. Since this data of non-project time is not used for any purpose by today, it is worth considering whether it should be continued to collect or not. By today it is stored in excel files and it is complicated to overview and requires filtering and extraction of rows to analyze.

After speaking to managers at the different units, it seems like the standard way of time reporting. The FUTAC standard, has not been launched and communicated throughout the organization with sufficient distinctness. A suggestion of improvements would therefore be to launch this standard with a workshop or similar and clearly communicate the importance of reporting also the non-value added time and the purpose of doing it.

The non-value added time occurred not only, as thought of before, in the reported non-productive hours. These hours are harder to identify, since they are hidden among the time paid buy the customer and by company definition therefore are seen as productive. To report different categories of project time in the same manner as the non-productive time is performed today could help identifying these hidden hours. However, since the time reporting is not fully functional as it is today, it may be ineffective to add even more categories. Many interviewees described the process of reporting by using the different time codes and manually load it into the ERP system as boring, complicated and time consuming. Today the employees use only the codes they can keep in mind, since they are listed in a separate Excel sheet. A new interface and a faster and more intuitive way of reporting time could be worth considering, with all the different categories integrated into one system. However the first thing to consider would be the main purpose with the time reporting and how detailed it would be, the second would be to reach out with that idea to the entire organization.

A basic requirement for time reporting system to work as intended is that there is no incentive to do it the wrong way. There must be no incentives such as bonuses or KPIs that makes it profitable to report fewer hours than are spent in reality. This would either lead to increased administration hours or that employees get paid for fewer hours than what is actually performed. Adjusting hours in order to achieve right margins and profits might helps to achieve the goal at the moment, but it also makes the measurement system less reliable and the organizational results less effective.

8. Control

The main objectives of the control phase is; to set a plan for how to make the process proof for mistakes and to provide a measurement plan for the future (George et. al, 2005). In this project the control phase are recomendation of future actions that has been handed over to stakeholders involved in the certain issues. Each proposed control action are showed connected to each x-factor in the sections below.

X1 – Use of different CAD tools – phase out of AutoCAD
In order to ensure the suggested actions related to the problems related to the different CAD tools used - some control actions are suggested.

The first control action would be to count how many drawings that are produced in FLDT globally, in proportion to the total number of drawings. Suggested is to make this count every six months in order to see how the trend looks. A settlement of AutoCAD and increased usage of FLDT should correspond to an increase in the global number of FLDT drawings per total number of drawings. This would require a counter function in the new PLM system ARAS. This recommendation was handed over to the Engineering tools department. By today, all the drawings are stored locally and therefore this measuring can start first when the new PLM system is implemented. Suggested KPI would be:

$$\boldsymbol{KPI_{X1}} = \frac{Number\ of\ FLDT\ drawings}{Total\ amount\ of\ drawings}$$

If the suggest KPI would not decrease over time it would indicate the usage of FLDT has not increased in comparison to the total number of drawings. It would then be of interest to see if the usage of other CAD tools has increased or decreased. The use of AutoCAD should decrease approximately the same rate as the use of FLDT increases. Large projects should also be kept outside of these statistics as they are made almost exclusively, due to technical requirements, in Inventor. The Engineering Tools department is preparing to visit the units around the world and provide training in FLDT so that its strengths and benefits reach out to the whole organization.

X2 – Re-drawing
To monitor the trend of the occurrence of re-drawing, some measurements suggest to be made with continuous intervals have been suggested. It is of interest to know, over time, how many projects that have drawings from more than one CAD tool. Projects with more than one drawing indicate that re-drawing has occurred. This data collection has started by this project and the data gathered from polish project the fall of 2016. Poland has the largest interaction and exchange of projects drawn at another unit, which means larger risk of using different CAD tools. Therefore the number of re-drawn projects in Poland is considered to be a representative indicator and metric for the occurrence of re-drawing at the company. Suggested KPI would therefore be:

$$\boldsymbol{KPI_{X2}} = No.of\ projects\ in\ Poland\ with\ a\ drawing\ from\ more\ than\ one\ tool$$

If there is no decreasing trend, a possible action would be to carry out a new Green Belt project, or similar, investigating this variation and trace the root causes. The new export function between FLDT and Inventor must be ensured it has been both released and are used. It should also be ensured to use the same CAD library, FlexCAD that has already been set as company standard. However, it may happen some units fall back to old habits and continues to use old local data bases. This could hinder the cooperation between the units and cause re-drawing and should be clearly communicated by management, which standard to follow.

X3 – Handover assembly – new drawing standard
In order to ensure the new drawing standard is used, it has been added as a checkpoint on the company's internal audit, which take place each year. It will mean a binary check, yes or no, to see if the new standard is fulfilled or not. If these are not fulfilled it will be each local managements responsibility to ensure the new standard is followed and fully implemented as the standard way of working. The internal audit is done in parallel with the external audit of the IS0 9001 quality management system.

Today there is also no global owner of a process like this, instead the responsibility of guidelines according to a standard way of working is handled and communicated by local management. This creates a risk of local adjustments of the process that may complicates the cooperation and exchange of projects and hours between the different units. It may be possible the new standard also causes less re-drawing, since some projects are re-drawn today in Poland only because the Assembly workers in Poland may be used to another level of information on the drawing than the sending operating unit are using.

9. Result

In this section the result from the empirical part will be summarized and presented.

One of the first findings, which also had a major impact on the study and the results, was the imposition of the existing measure system of time reporting. It was performed in many different ways at different units. Therefore, the existing data was not considered useful for the project. What was reported as project time and not differed between the units and the non-productive time was either not reported or done with different categories. This prompted collection of new data.

From the interviews and visits made before the conduction of the survey, some considerable things was revealed. At first, a use of different CAD tools and CAD databases between the different units was noticed. This was causing problems when transferring files and exchanging projects between the units and often led to re-drawing. Another consequence was that no cooperation between these units took place at all, due to the conflicts in engineer tools used. The caused re-work was most often not seen as waste among the engineers. The time the re-work took was instead invoiced to the other operating unit. An additional finding from the interviews was the lack of structure to store old projects and knowledge. This finding was handed over to the ARAS project developing a new PLM system, which most likely will solve these issues. The handover documentation from PE to Assembly differed between the units as well as the handover of between AE and PE. An parallel ongoing project was focusing on that specific handover, between AE and PE, therefore it was kept outside this project.

Main part of the result from the Measure phase was from the qualitative part of the survey, i.e. the diary notes from the participants. The quantitative result was mainly used to categorize and circle some areas where most problems seemed to occur. From the qualitative part some findings were made and highlighted. However, some of the findings were not further analyzed and left outside the project scope. Examples of such findings were; individual IT issues, a few shipment and logistics issues and time spent on company training activities. The training was considered to be value-added and therefore not focused on any more.

The findings from the Survey from which a systematic pattern of affinity could be identified were further investigated.. Under the methodology of Six Sigma these are called x-factors, since they have a critical effect on the output of the result, and mitigating of them could cause less variation throughout the process.

The chosen x-factors to put focus on were; *Use of different CAD tools, Re-drawing* and *Handover Assembly.* The first x-factor, called *X1*, was focused on the different CAD tools; a factor that causing several problems, mainly when transferring files and CAD models between different operating units. In that sense it isolated the units using AutoCAD from the rest of the units. AutoCAD was also less and less maintained and was not compatible with the new CAD library of standard files, FlexCAD. Possible savings in phasing out AutoCAD and increase the usage of FLDT was estimated to 1.4 MSEK.

The second x-factor, *re-drawing*, can partly be seen as a consequence of the use of different CAD-tools but other causes were also found. A general observation was that re-drawing is not always seen as waste among engineers and managers. The perspective of re-work was normalized as general work that was rather considered positive than negative. This since the total number of hours could be increased and hence the revenue of the operating unit. However, from a global perspective; it hinders the organization to be more efficient and to expand and grow according to the company goal and strategy. It was concluded that changing this attitude could improve the organization making it more streamlined and efficient. Hence leave room for an increased number of projects, and hence enable an increase of sales without hiring as many consultants or engineers. Implementing the new export function between FLDT and Inventor will also prevent this type of re-drawing from occurring. However, in the same manner as with the new CAD library; there is a need for the organization to communicate this and convince everyone in the organization to start using the new function. Training of FLDT will be offered through the Engineering tools department.

The final x-factor, *lack of drawing standard,* is more of a prerequisite to further development of the processes. The lack of complicates the investigation of variations in faults and error occurring in the assembly. A first step, in the investigation of where the problems in the assembly origins from, would be to ensure enough information has been handed over. Therefore an existing standard was agreed upon after several meetings and a final video meeting including all the four units. The control of the enforcement of the new global standard was added as a checkpoint to the internal audit checklist. This in order to ensure the standard is followed over time.

10. Conclusion

In this section the connection between the research questions, the empirical result and existing theory will be presented. As the last part of the section the three research questions are summarized and answered.

One of the first major conclusions was the condemnation of the existing measure system of time reporting data. It was considered non-valid to use for further analyze in the study. Major reason was the fact that it is carried out in such different ways at the different units. Therefore the survey was conducted. Even in the survey, that had clear guidelines and instructions, it showed that it was hard to fully trust the quantitative data. Most of the result came from the qualitative comments from the diary part of the survey and from the observations and interviews. Suggestions were given in order for the management to figure out the purpose with the time reporting and to communicate that clearly to all within the organization. It fits well of what Tushman & Nadler (1997) concluded about *problem of anxiety* and *problem of organizational control.* It must be clearly explained *why* this new FUTAC method should be used, and *what* is in it for each employee. Further also manage to get this message out to the organization by using adequate tools and methods. The conclusion of Ahlstrom (2004); the definition of non-value-added activities in services and non-productive processes is subjective. The perception of what should be reported as non-value-added time differs between the operating. The same as the definition of *re-work*.

The study identified three critical inputs, x-factors, to the project execution phase, i.e the PE process. One of the x-factors, hand-over documents assembly, is nearly related to the existing research regarding the feedback loop between upstream and downstream processes (Wheelwright & Clark, 1992). It is not fully comprisable since the investigated PE process is not a traditional product development process, but instead a modular design process performed by one single engineer. The downstream process, assembly in this study, does not have to be designed and ramped up as in new product development projects. Despite that distinction, some similarities with the existing literature have been identified. Wheelwright & Clark (1992) concluded that this type of one-shot handover of information would cause surprises for the downstream group. Especially for those unique and special parts of a certain project. It corresponds well to the PE projects where all the projects are to some extent unique and often includes parts from external suppliers. The first step against these surprises would be as recommended; to ensure the handover drawings follows the same standard, prerequisite for future improvements of this concerns. To introduce earlier involvement of the downstream group may be difficult since the projects are relatively fast developed, normally around one week in Engineering time of a mid-sized project.

Regarding LSS as a method for this type of process and project, it has been concluded as feasible. A significant result of using LSS was the *Establishment a thinking of Continuous improvement* per Shaffie & Shahbazi (2012). The LSS method helped to put all the facts and statistics related of the project, into context and filed credibility. The result was presented through video meetings and the different units held constructive discussions and common solutions were agreed upon. One example of those cross-sectional meetings was the agreement upon a new common drawing standard that will be launched in 2017.
These agreements were made despite cultural differences and independent ways of working at the different units, the LSS methods and tools contributed to this and showed out to work across organizational borders.

Intangible costs according to the definition of Shaffie & Shahbazi (2012) were also identified. The cost of having a high skilled personnel at the UK unit without utilizing it fully is hard to estimate. A trend in decreased turnover and a shrinking domestic market has been hard on the UK unit. However, the competence still exists and there is a cost of not distributing this knowledge to the rest of the organization. More integrated CAD tools and systems could enable outsourcing of engineering projects to the UK unit and hence contribute with their high level of skills to the rest of the organization.

10.1 Research questions

Below each research question is answered. The answers are a summary of the empirical results.

RQ1 –Which are the main critical to quality factors contributing to unwanted variation of the project execution process?

The identified critical to quality factors were; the *use of different CAD tools* that was causing conflicts complicating the co-operation between, e.g. the exchange and outsourcing of engineering projects between the units. It lead to re-work when transmitting drawings and CAD models from different CAD programs. *Re-work* itself was addressed as another critical to quality factor. This since rework sporadically occurred when not necessarily needed. It was seen as a normal value added part of the daily job. The third factor was the handover documents between Project Engineering and Assembly. A global standard of drawings was lacking and a new standard was agreed upon.

RQ2 - What actions should be taken in order to mitigate the impact of those x-factors and steer them into controllable factors?
A phase out of AutoCAD and an increased use of FLDT would mitigate the rework and conflicts of transferring files between the operation units. The term rework must be clearly explained throughout the organization and clarified that re-drawing is equal to waste and should be avoided to any sense. Mindset in the organization should be to make the global process more efficient rather than increasing the amount of project hours at one single operating unit. Re-drawing is in that sense increasing one unit's invoiced hours but will make the global organization less efficient. A new drawing standard has been agreed upon and

introduced. This enables further root cause analysis work concerning the problems occurring in the assembly.

RQ3 – To which extent was it feasible to use LSS methodology in order to improve a project execution phase within an automation solution company?

LSS has been concluded feasible for this type of process and project. A significant result of using LSS was the *Establish a thinking of Continuous improvement* per Shaffie & Shahbazi (2012). LSS as a method was powerful in order to put all the facts and statistics into context. The result was presented through video meetings and the different units, were constructive discussions were held and it was agreed upon common solutions. One example of those unit cross-sectional meetings where the agreement upon a new common drawing standard.

These agreements could be made despite cultural differences and independent ways of working at the different units. The result showed that some fundamentals of traditional Six Sigma, as the data analysis, was less feasible and than the map-up of processes and the establishment of a common language. Which in turn can be seen as a result of the subjective data, dependent on the participants.

11. Discussion

The study was a case study, investigating one single example. However, no documented research has been found investigating a certain process as in the study; a project execution phase within the automation solution industry. Therefore this study can state as an example of proving the expanses and flexibility of LSS methodology. The study has shown what strengths and weaknesses LSS has for a certain process.

More specifically some lessons are learned that could be valuable for future research. Firstly, the execution of a survey is challenging, since it is performed at a distance from where the action is. It is even more challenging to involve four different countries and to get everyone understand and do it right. A lot of time was spent on designing the survey and preparing for the compilation of the survey data. In retrospect, the time spent on the survey would might have been more appropriate to spend on more interviews. However, the aim of the survey was to collect data in the exact same way during the exact same period at four different units in order to get a cross-section of problems occurring. The survey did in fact deliver critical findings and patterns of causes were identified.

One general conclusion from the survey is that this type of data collection is hard to carry out remotely and not be located at each unit. It is challenging to ensure everyone has got adequate information and are fully dedicated to the task of filling out the survey. When increasing the number of participants it generates a better cross-section of the population. However, it also enables the participants to easier hide as one in the bigger crowd and hence get less dedicated. The level of English skills also differs remarkably between the units. It is likely to believe that some of the participants, those who were sorted out from the result, did not fully understand the task due to linguistic obstacles.

Some of the findings and solutions were already developed by the company. An example is the drawing standard that had been developed already in June 2016 but then remained in the archives and was not launched to the rest of the organization. A few examples of that kind were identified. When these solutions were put into context of the LSS project it was experienced easier to gain support and get someone to take action and continue to work on these more or less finished but archived solutions.

A lot of time was spent on Financial theory and investigation of financial calculations in order to ensure the project did economic benefit. Another time consuming activity was the investigation of the existing time reporting data, which included 70000 rows in Excel and were complex and time consuming to analyze. However, financial model and measure system are two central aspects of Six Sigma on which a lot focus needs to be put to ensure the project aims to improve something that has the right organizational rootedness.

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Appendix

Appendix I

Effective Scoping

Why?

1. *What comes out (of the physical process)?*

Detailed Assembly drawings and Bill of Materials (BOM)

2. *Who uses the output?*

Assembly fitters and supply chain workers (purchase), later installation and end-customer

3. *What is required of the output from this particular user (customer – user of the output or process owner monitoring with a KPI)?*

The drawings and the BOM should contain enough information so that any of the assembly workers can manufacture the product with no need of asking questions or no need to make any changes of the drawing. Exceptions can exists at the smaller units.

What?

4. *What one measure (Y) should be understood and improved? How will you know when the intended improvements are accomplished?*

The capital Y of the project is the administration time in engineering projects.

5. *What is the baseline of the Y and can (with the right precision) that precise Y measured today (objective)?*

At Engineering Projects at FlexLink in Europe today, an average of 75% of the Project Engineers and Project Managers time are reported as project time, the rest becomes Sales and Administration costs.

6. *What other Y cannot be lost in process (constraints)?*

The recovery rate.

7. *Process: team/project jurisdiction of changes; what competences are needed in the team?*

Six sigma Black Belts + mentor (champion). People with insight in the project process, both in detail and holistic, support from financial department and global and local management.

How?

8. *What are the inputs to the system? Who supplies the input?*

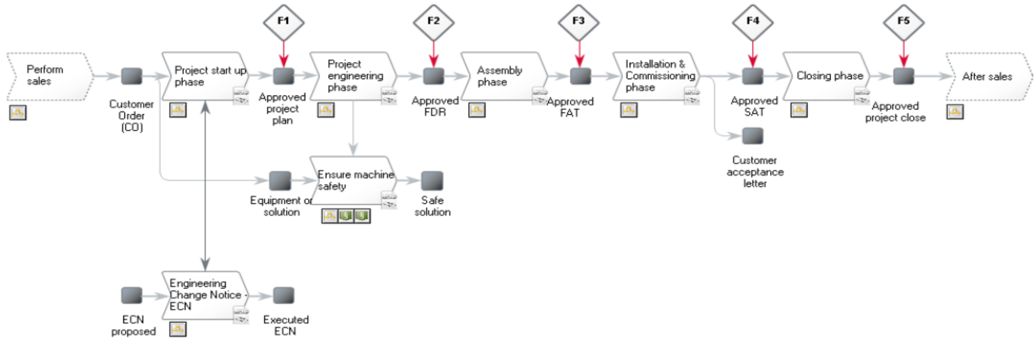
From Application phase: A layout of the product approved by the end customer and developed in FlexLink Design Tool (FLDT). Also a customer specification and Sales hand-over documents including the quotation.

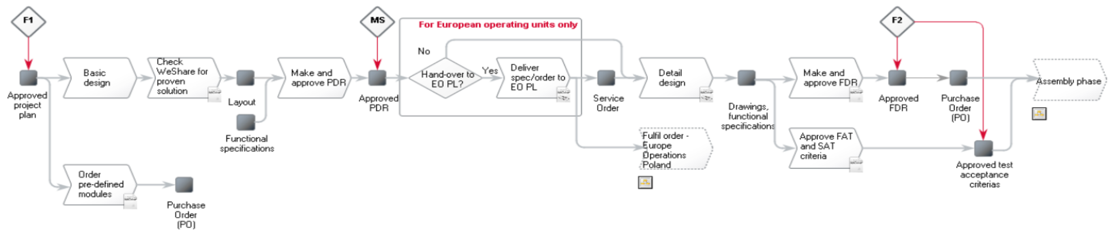
From Financial department: An approved budget with allocated resources.

9. *What does the system require of the input?*

All the necessary documentation completely filled-out to be approved by the customer and the Financial department.

Appendix II


F1
F2
F3
F4
F5
Perform sales
Customer Order (CO)
Project start up phase
Approved project plan
Project engineering phase
Approved FDR
Assembly phase
Approved FAT
Installation & Commissioning phase
Approved SAT
Customer acceptance letter
Closing phase
Approved project close
After sales
Equipment or solution
Ensure machine safety
Safe solution
ECN proposed
Engineering Change Notice ECN
Executed ECN


F1
MS
F2
For European operating units only
Approved project plan
Basic design
Check WeShare for proven solution
Layout
Functional specifications
Make and approve PDR
Approved PDR
No
Hand-over to EO PL?
Yes
Deliver spec/order to EO PL
Service Order
Detail design
Drawings, functional specifications
Fulfil order - Europe Operations Poland
Make and approve FDR
Approved FDR
Purchase Order (PO)
Approve FAT and SAT criteria
Approved test acceptance criterias
Assembly phase
Order pre-defined modules
Purchase Order (PO)


Equipment or solution
Ensure machine safety
Safe solution
ECN proposed
Engineering Change Notice ECN
Executed ECN

Appendix III

Problem Statement

The Perception is that FlexLink project engineers use to much time in other work but projects. This time is unproductive . Today not all hours are reported in "time-categories" so it is hard to follow and hence work to reduce the non value added time.

Project Objective - Voice of the Customer

Measure how much time is spent on non-productive hours and after that define a goal on how to reduce hours spent on non-productive hours for project Engineers. The recomendation should be implemented as a pilot in Nordic, Polan, Germany and UK

Metrics and Goal Statement

Project Y's	Units	Baseline	Goal	Comments
Reduction of recovery rates	€	2,223k€	2,001k€	10 % reduction of admin hours

Idecrease the delay in opertaig units by better tools to control

In Scope: Project Engineers, Project Managers and Project Administration.

Out of Scope: All other financial administration

Business Case

Constraints & Dipendencies

Constraints:

Dependencies:

Project Risks & Opportunities

Project Benefits

Type of Benefit	Basis of Estimate or Qualitative description	Est. Benefit
Specific Cost Savings		€ 222 380
Enhanced Revenues		
Higher Productivity		
Improved Compliance		
Better Decision Making		
Less Maintenance		
Other Costs Avoided		
	Total Quantitative estimation	€ 222 380

Project Team

Name	Organization
Rickard Stigh	Projects Manager FLNO
Grzegorz Lefler	EOPL
Pernilla Alvstrand	FlexLink HQ
Bjarke Johansen	PSD Production centre

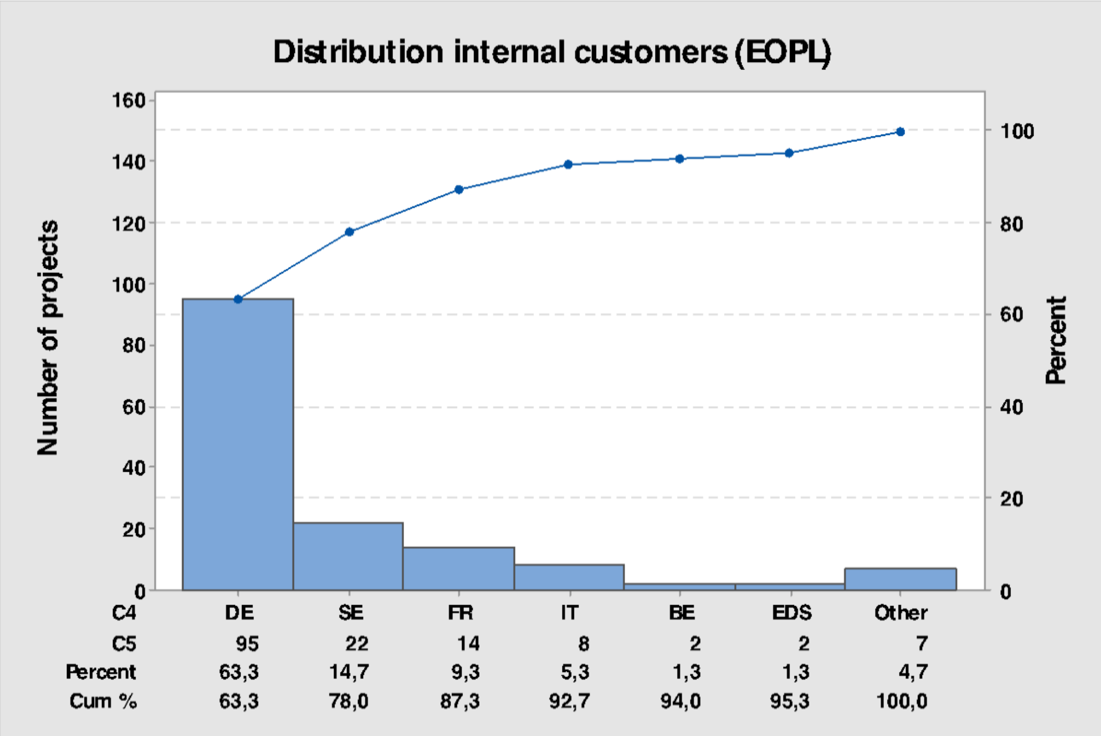
Stakeholders & Advisors

Name	Organization
Mattias Byström	FlexLink HQ
Jon Bagiu	Area Director
Serge Abou-Jaoude	Area Director
Stefan Pedall	EOPL

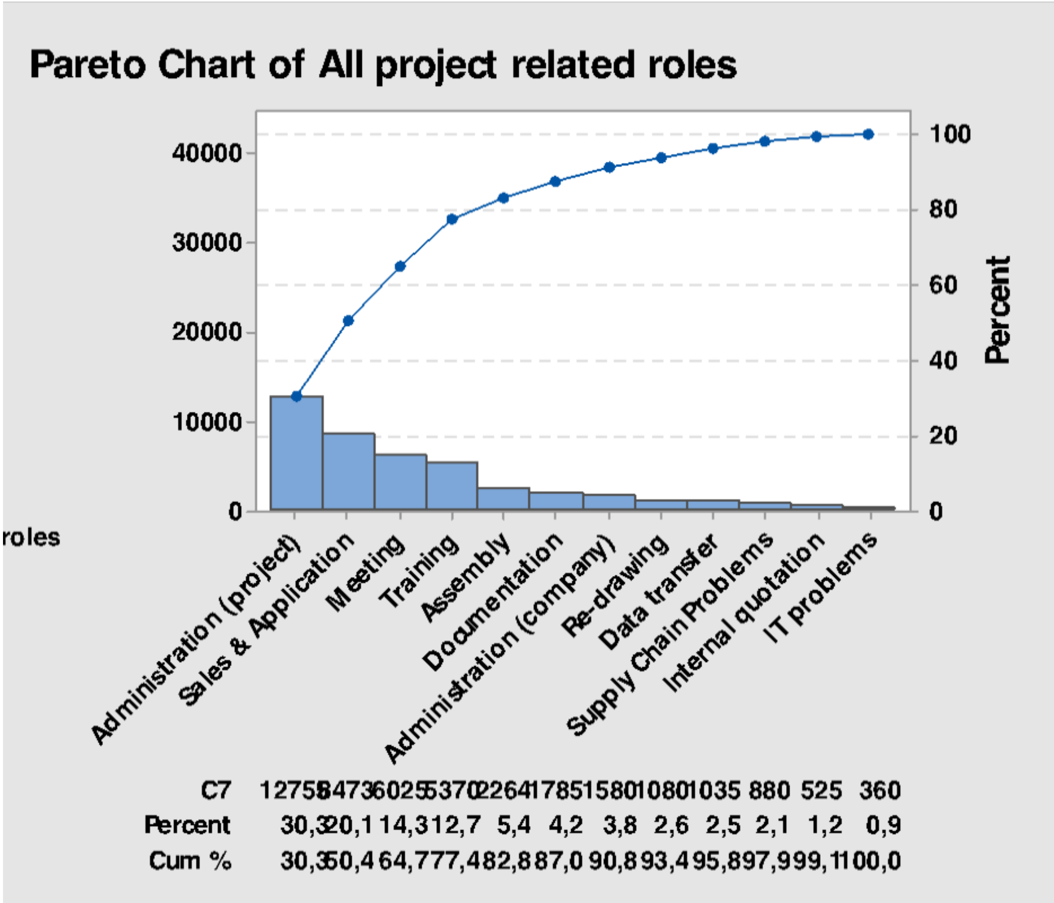
Project Approval

Role	Name	Signature	Date
CEO	Mattias Byström		
BB	Bartosz Kaszynski		

Appendix IV


Distribution internal customers (EOPL)
Number of projects
Percent
160
140
120
100
80
60
40
20
0
100
80
60
40
20
0
C4 DE SE FR IT BE EDS Other
C5 95 22 14 8 2 2 7
Percent 63,3 14,7 9,3 5,3 1,3 1,3 4,7
Cum % 63,3 78,0 87,3 92,7 94,0 95,3 100,0

Appendix V



Pareto Chart of All project related roles
40000
30000
20000
10000
0
100
80
60
40
20
0
Percent
roles
Administration (project)
Sales & Application
Meeting
Training
Assembly
Documentation
Administration (company)
Re-drawing
Data transfer
Supply Chain Problems
Internal quotation
IT problems
C7 12758 8473 6025 5370 2264 1785 1580 1080 1035 880 525 360
Percent 30,3 20,1 14,3 12,7 5,4 4,2 3,8 2,6 2,5 2,1 1,2 0,9
Cum % 30,3 50,4 64,7 77,4 82,8 87,0 90,8 93,4 95,8 97,9 99,1 100,0