CHALMERS
UNIVERSITY OF TECHNOLOGY

Suggestions on quality improvements on an assembly line

Bachelor thesis in Economics and Production Engineering

Cindy Liao

Vi Tuong Thai

DEPARTMENT OF TECHNOLOGY
MANAGEMENT AND ECONOMICS
DIVISION OF SUPPLY & OPERATION MANAGEMENT

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2020
www.chalmers.se
Report Number: E2020:007

Report Number E2020:007

Suggestions on quality improvement on the assembly line

Cindy Liao
Vi Tuong Thai

Supervisor: Dan Edblom, Volvo Group Trucks Operation
Supervisor: Riikka Kaipia, Department of Technology and Economics
Examiner: Riikka Kaipia, Department of Technology and Economics

CHALMERS
UNIVERSITY OF TECHNOLOGY

Department of Technology and Economics
Chalmers University of Technology
Gothenburg, Sweden 2020

Suggestions on quality improvement on an assembly line

Cindy Liao
Vi Tuong Thai

Report number: E2020:007
Department of Technology and Economics
Chalmers University of Technology
SE-412 96 Gothenburg, Sweden
Phone: +46 (0)31-772 1000

Gothenburg, Sweden 2020

ACKNOWLEDGEMENTS

During our bachelor's program, economics and production engineering at Chalmers University of Technology, we have been introduced to the fields of lean and quality in the manufacturing industry, hence a great interest in whether quality can be improved have grown. The knowledge we have gained from the courses can be applied in this thesis by studying and analyzing the production environment.

The Bachelor's thesis corresponds to 15 credits and was designed by us together with the supervisor at Volvo Group. This study included many visits to the factory and literature studies for a better understanding of the current situation.

We would like to thank our supervisor and examiner Riikka Kaipia who helped us during the project and gave us valuable feedback and provided us with guidelines for theory and knowledge in the field. We are also very grateful to our supervisor at the company, Dan Edblom, who provided us with important information about the area, materials, and contacts, answered our questions, has been engaged, supportive and guiding. Finally, we also would like to thank all the team leaders, the quality department and other personnel at Volvo Trucks who have been involved in various ways during the study, participated in interviews and have been accommodating.

_____ _____

Cindy Liao **Vi Tuong Thai**

ABSTRACT

Prior research about quality management in automotive industry focuses on satisfaction, e.g. customer that are satisfied when buying a product. Moreover, this paper will focus on studying the quality management in Volvo Group Trucks.

The purpose of this thesis is to study ways of working and provide suggestions for future improvements in the assembly line with the help of literature that has been studied. The research questions of the study are: “How can quality management be improved on the assembly line at Volvo Trucks?” and “How does deviation reporting affect quality management on the assembly line?”

This Bachelor’s thesis is carried out at Volvo Trucks, which is a part of the Volvo Group. The company is currently working extensively with paper in the main line of the production, the assembly instructions for the trucks are on paper, even the deviation card they use for writing down the deviations occurring during the assembling of the truck. This way of working leads to the quality on the assembly line not being perfect.

The methods that were used in this study are interviews with different team leaders and the management. Moreover, observations at the assembly line were made to get a better understanding about the current way of working. Too increase the validity of the study, literature about the topic were studied.

The findings indicate that there are different ways of improving quality management. Foremost, creating an own philosophy is preferable according to lean production, since is a huge factor when it comes to quality improvements. Industry 4.0 and digitalization are possible solutions combined with lean production to improve quality. Furthermore, the data quality in deviation reporting is an issue regarding quality management, due to the inaccuracy and lack of quality in the reports. Since deviation reporting is a big part of the quality management, especially in production, it is important to identify how the deviation reporting affects the assembly line at Volvo Trucks.

The suggestions provided to Volvo are valid for future studies to improve the quality management on the assembly line. Moreover, there are suggestions regarding employees and continuous improvements that could be implemented today. However, it requires the company to provide the right prerequisites for the implementation.

Table of Contents

1. Introduction

1.1 Background

Quality is defined as the ability of the product or service to satisfy the needs of customers (Nationalencyclopendin, 2020). Therefore, an essential factor for customers when buying a product or service is quality. According to Bergman and Klefsjö (2012), companies that work with quality and quality development tend to have a higher success rate in market sharing, lower internal costs and are quicker to develop new products. In a quality perspective, works such as detection, adjustment, prevention of defects and continuously improving the quality in production require special involvement from workers. Companies, such as Volvo that work with assembly lines have established quality control departments to monitor the deviations and defects from the workers (Mateo, 2008).

As mentioned by Rojko (2017) quality management cost can be reduced by Industry 4.0. In order to reduce the cost, quality needs to be improved. Quality improvement is connected to several philosophies and most of them agree that a successful quality is achieved by putting the customers first. Therefore, making rational decisions based on facts and involving the entire company to work on continuous improvement of processes, which is crucial when it comes to improving the quality (Bergman & Klefsjö, 2012). According to Robert Azrak, Senior Quality Manager at Volvo Trucks, improved quality can lead to reduced cost by removing activities such as quality controls and the cost for work to re-do or replace deviations on the assembly line. Azrak also argues that improved quality is not only based on the product quality but also on processes, since they are connected to each other.

The automotive industry is evolving and going through changes frequently to adapt and meet customers' demands. One of the most common concepts used to achieve and satisfy the demands is Industry 4.0. The reason for this is to implement smart manufacturing, for example digitalized and automated processes (Schumacher, Nemeth & Sihn, 2018). According to Tortoella & Fettermann (2017) by implementing automated equipment, product quality can be improved and the efficiency of the processes for manufacturers. Furthermore, cost in logistics, production and quality management can be reduced by 10-30% by implementing Industry 4.0 into the organization (Rojko. 2017). The whole concept of Industry 4.0 is basically to create value and connect the entire supply chain, to be more flexible, sustainable, and efficient during the process (Machado, Winroth, Carlsson, Almström, Centerholy & Hallin, 2019).

One of the philosophies that is connected to quality improvement is lean production. The philosophy is based on the Toyota Production System (TPS) (Liker, 2004). One of the fundamentals of lean production according to Juran (2010) is to eliminate non-value-added work. This mean that activities that do not provide any value to the customers will be removed or reduced, e.g. deviations and re-works. Additionally, improving the efficiency in all processes and working to continuously improve can help to obtain quality throughout a low cost. Hence, a misconception that most companies are having when it comes to implementation of lean is that they are just scratching the surface of the production system, since in their perspective, most of the time are based on the tools and techniques within lean, but are missing the whole picture by not involving the whole organization (Hines, Holweg & Rich, 2004).

The thesis will be performed at Volvo Trucks Tuve, where the final assembly of heavy-duty trucks occur. The process contains high degree of product variation and higher level of variation

will most likely decrease the possibility to improve efficiency, ergonomics, and quality. Therefore, the focus of the study will be to analyze the current situation regarding quality management and give suggestions for improvements for future investments.

In the current situation, Volvo Trucks are facing challenges when it comes to quality. A short and simple answer to that is the high level of product variation, however that is not the whole truth. One of the challenges that have been identified is the data quality is lacking when it comes to deviation reporting. Since the current way to report a deviation today is through a deviation card, which is done manually by either an operator or a team leader. So, one way to improve quality is to identify deviation and thereafter find a solution. Therefore, the importance of deviation reporting is very crucial. Hence, the data quality needs to be accurate in order to improve the overall quality.

1.2 Aim

The aim of the thesis is to study ways of working with quality management in Volvo Trucks Tuve and give suggestions to improve the quality on an assembly line.

1.3 Research questions

- How can quality management be improved on the assembly line at Volvo Trucks?
- How does deviation reporting affect quality management on the assembly line?

1.4 Delimitations

The report will focus on searching and collecting information about quality in the automotive industry as well as possible theories of improvement. This information will be used to draw feedback on the current situation in the assembly line at Volvo Trucks. The literature research will be delimited into lean management/production and quality management. The study is limited to the day shift and the problems that occur during working hours. The reason the study is limited to day shift is because the evening-shift works differently and it is limited with workers who can support the study. There may be differences between the two shifts, since the evening shift is working with less personnel, which lead to higher workload for the operators. Therefore, the results can be differing from the shifts.

2. Theoretical framework

This chapter describes quality, lean production, digitalization, and their conceptual definition but also quality from the perspective of the following stakeholders: employees, organization, customer, and supplier. Thereafter, lean production will be described by the principles from Liker (2004).

2.1 The importance of quality management

The interests of the quality and quality enhancement have meant that the term is often used, and the purport and the view people have can differ. Even the various foreground figures in the quality area have defined the word in different ways. Philip Crosby, a quality guru, mentioned that quality means "conformance for requirements" (Bergman Klefsjö, 2012, p.21) but according Juran (2010, p.5) quality meant "fitness for use" and Deming went further in customer focus and meant that "quality should be aimed at the needs of the customer, present and future" (Bergman Klefsjö, 2012, p. 22). However, the authors Bergman and Klefsjö describe the concept of quality according to following definition "the quality of a product is its ability to satisfy and preferably exceed the needs and expectations of customers" (Bergman & Klefsjö, 2012). Yet, high quality affects not only customers but also other stakeholders such as employees, organizations, suppliers, and society, all of whom can benefit from good quality (Bauer, Duffy & Westcott, 2006). Stakeholder's connection to quality is described in more detail below.

Good quality is desirable for all organizations, not least for production operations. The quality aspect is interesting and benefits the organization as it is an example and shows how well the productive and cost-effective use of the resources are, i.e. how well the resources are invested in the organization (Bauer et al., 2006). The processes that generate high quality products also result in lower costs for, among other things, repairs, duplicated work, warranty measures but also give recurring orders from customers and thus sales revenue, increased reputation and, at best, increased market share. Good quality can provide marketing benefits and competitive advantages (Ax, Johanssons & Kullvén, 2015). By possessing good quality, organizations can instead invest in continuous improvement, assessment of the current situation and prevent poor product and quality of service, which is appreciated by the customers. Disposal of a component or item generates a loss of time, material cost and moreover, the labor cost i.e. the added value. Due to the lack of quality, the system's productivity also decreases (Bauer et al., 2006).

Companies that aim for high quality in their products, usually work closely with their suppliers and share information to ensure that the suppliers understand the organization's requirements but also to make the organization aware of the suppliers' ability. This partnership that is established can lead to better communication which in turn allows any to be solved before they become serious and that common goals can be reached. Thus, suppliers also benefit from working with organizations that work with quality (Bauer et al., 2006).

Quality benefits employees who are involved in production because it leads to an improved attitude to performance in question, i.e. that they have done their job to the best of their ability. In addition, good quality contributes to the employees feeling certain security regarding their employment. The authors also describe that products of high-quality systems and processes also

benefit employees because accurate and complete documentation reduces errors and makes the employees' jobs easier and allows development (Bauer et al., 2006).

2.2 Quality management in automotive industry

A way to deal with the quality management in the automotive industry is by quality standards, ISO 9001 (Goicoechea, & Fenollera, 2012). ISO 9001 is a standardized management system for the business processes of a company or organization. A management system describes the way for continuous improvement and how to adjust the business to meet the demands from the customers (Cianfrani & West, 2013). Employees, middle managers, and top managers find it embracing to use ISO 9001, the opinions are summarized in points below (Cianfrani & West, 2013).:

- Workers get opportunities to bring up problems and discusses confidentially.
- Workers will not be blamed if they cannot solve a problem that is supposed to be solved by the managers
- Middle managers find the problems are easier to solve and the variability is reduced because ISO9001 have made their way of working standardized.
- The management has become less difficult because the decisions are based on facts and data.
- The ability to understand and meet the demands of the customers in agreement have improved.

2.3 Quality improvements techniques

There are various philosophies that relate to improvement, partly that improvement can be achieved gradually and partly through radical change. A successful quality is based on the organization putting customers at the center, the management making decisions based on facts, and engaging all employees in a continuous effort to improve all the company's processes, both in development and administration as well as manufacturing. A solution to engage all employees is to use the quality circle, which means problem areas are highlighted and proposals for solutions are discussed by a group of the employees from the company, Thereafter, agreed improvements are introduced in the workplace (Nationalencyclopedin, 2020). The American Joseph M. Juran who has had a great influence on the development of quality technology also points out the importance of management's decisive role (Bergman & Klefsjö, 2012). To emphasize the importance of the management's commitment and the idea that quality work must permeate the entire company, terms such as kaizen and six sigma will be described in more detail below.

2.3.1 Six Sigma

The term six sigma was introduced in 1986 by Motorola, as a part of their work on improvements. Since then many organizations have implemented this method and achieved a good result. The main purpose with this method is to eliminate defects within processes to improve the outcome of the quality. The definition of six sigma quality is to get 3.4 defects per millions. A defect is defined as the crucial properties that are insufficient for the customer (Desai & Kishor, 2010). The six steps to achieve the six sigma quality in manufacturing is following (Dahlgaard & Dahlgaard Park, 2006):

- Identify physical and functional requirements of the customers
- Determine the critical characteristics of product
- Determine for each characteristic, whether controlled by part, process, or both
- Determine maximum range of each
- Determine process variation of each characteristics
- ID process capability is less than two then redesign materials product, process as required

DMAIC is a method for improvements in six sigma and is defined as (Dahlgaard & Dahlgaard Park, 2006):

- Define – At this stage, the starting point is set. A complete project plan with the problem described, measurable goals, cost consequences and timetable are being prepared.
- Measure – This step is about evaluating the current state of the processes and performing data collection. By studying the output (Y) and the input (X), analyze processes to identify defects and variations. This is to create a comprehensive understanding of the processes and thereby find the root cause of the problem.
- Analyze – A detailed analysis is done to determine and verify the causes that have the greatest impact on the output and input. Using statistical tools, the factors that have a big impact on the result variable are linked together.
- Improve - potential solutions are developed and then implemented in the process. In cases where there are several solutions, the best solution can be chosen with the help of Pugh matrix. In some cases, a combination of multiple solutions may be the best solution.
- Control – This is the final part of the method; at this stage it should be ensured that the improvements that are obtained through the project are also maintained after the project.

2.3.2 Kaizen

Kaizen means “change for the better” and are known as rapid improvements events (RIE). The goal with kaizen is to eliminate waste and remove activities that are not value added. The concept of kaizen is to organize events with focus on specific improvements, during these events employees at all levels are involved to develop solutions for improvements (Liker & Meier, 2006, p.21). It is stated that standardization must exist otherwise there will be no kaizen, that is because standardization is a starting point for continuous improvement. If the work variates every time, there will be no basis for the evaluation.

2.4 Customer adaptation

The definition of customer satisfaction is to be able to meet or exceed customer needs and requirements for product function, price, and performance. According to Bauer (2006), good quality and less defects can lead to increased customer satisfaction. Companies that work with quality will receive fewer complaints from customers because the product is delivered from staff with high knowledge, clearer processes, and thus fewer errors. For increased competition companies should offer customers personal service with high quality because it is proved that it is easier and cheaper to keep current customers that are satisfied than replacing the customers that are leaving (Bauer et al., 2006). Satisfied customers are also sought because of financial factors. Customer satisfaction means increased sales and growing profits and therefore long-term customer relationships should be of paramount importance for an organization. This has received more attention in today's organizations (Ax et al., 2005).

Since the end of 1980s, a new direction in manufacturing has been taken, shifting to from mass production to mass customization (Hu, Ko, Weyand, ElMaraghy, Lien, Koren, Bley, Chryssolouris, Nasr & Shpitalni, 2011). According to Hu et al., (2011) the number of vehicle models in USA increased by 121 from 1969 to 2006. These drastic changes can partially be explained by companies that want to differentiate themselves and be able to respond to the needs and preferences of consumers. (Hu et al., 2011). However, in today's global market, there are challenges that manufacturers need to consider, such as short product life cycles, new trends, unpredictable product demand and new technologies. Furthermore, manufacturers need to still provide high variety and, in a cost-efficient way (Bejlegaard, Brunoe, Bossen, Andersen & Nielsen, 2016).

There are different stages where product variety can be achieved, during design, fabrication, assembly, sales and in the adjustment phase (Hu et al., 2011). However, the assembly phase is the most beneficial of them, in a cost perspective way. Having a proper design of a Product Family Architecture (PFA) (Hu et al., 2011 & Bejlegaard et al., 2016), the product can be divided into module segments and thereafter several variants of the assembly combination can be provided. In that case, the variety will increase in the final products. This approach allows customers to change the basic product design and enable the production cost of customization to be at near mass production cost. Both economy of scale and economy of scope is achieved (Hu et al., 2011).

2.5 Lean philosophy as a quality improvement technique

An efficient way to obtain quality to a low cost is through lean production. Lean production is a philosophy that originated from the Toyota Production System (TPS). Lean can be described as a process of systems to reduce costs and wastes. The foundation of the philosophy is to eliminate non-value-added activities such as overproduction, unnecessary inventory, deviations, transportation etc., and to improve the efficiency of all processes (Juran, 2010). According to Liker (2004), lean manufacturing can be defined into five steps: defining customer value, defining the value stream, making it "flow", or "pulling" from the customer back, and striving for excellence. However, lean production can be misrepresented for just tools and techniques, but that is not the whole truth, since lean production or TPS is about continuous improvements (kaizen), respect for man, eliminating waste, standardize work and striving for greatness. In his book, "*The Toyota Way: 14 management principles from the world's greatest manufacturer*", Liker (2004) describes 14 principles that constitute the Toyota Way. These principles are presented below and are categorized into four segments, "*1) Long-Term*

Philosophy, 2) The Right Process Will Produce the Right Result, 3) Add Value to the Organization by Developing Your People, and 4) Continuously Solving Root Problems Drives Organization by Developing" (Liker, 2004).

1) *"Base your management decision on a long-term philosophy.*
2) *Create continuous process flow to bring problems to the surface.*
3) *Use "pull" systems to avoid overproduction.*
4) *Level out the workload*
5) *Build a culture of stopping to fix problems, to get quality right the first time.*
6) *Standardized tasks are the foundation for continuous improvement and employee empowerment*
7) *Use visual control so no problems are hidden*
8) *Use only reliable, thoroughly tested technology that serves your people and processes.*
9) *Grow leaders who thoroughly understand the work, live the philosophy, and teach it to others.*
10) *Develop exceptional people and teams who follow your company's philosophy.*
11) *Respect your extended network of partners and suppliers by challenging them and helping them improve.*
12) *Go and see for yourself to thoroughly understand the situation.*
13) *Make decisions slowly by consensus, thoroughly considering all options; implement decisions rapidly.*
14) *Become a learning organization through relentless reflection and continuous improvement."*

2.5.1 Be physically present

The 12th principle mentioned above by Liker (2004), "*Go and see for yourself to thoroughly understand the situation"* is referring to the definition of the principle, by physically going down to the production and seeing by your own eyes (Gemba). This principle is based on understanding the production or organization by being physically present. By seeing it with your own eyes, the fact of misunderstanding or misinterpreting will be eliminated. The reason behind this is that TPS do not based or trust their decisions from others. According to Liker, this is the first step to solve problems, however this principle does not only contain observations, but also requires a good capability to analyze and understand the situation. Because it is essential to solve the cause of the problems and not just correct it (Liker, 2004).

2.5.2 Fix the problems as soon as possible

Andon is a tool to help the operator call for backup, for instance calling the team leader if there is any problem or deviation on the assembly that cannot be corrected during the cycle time. To call for help, a signaling system for the operator activates either by a button or pulling a wire. The system can be connected to the 5th by Liker, "*Build a culture of stopping to fix problems, to get quality right the first time*.". which indicate the importance to stop the processes to build quality (Jidoka), however with the Andon system, this can be prevented since the meaning of "stopping to fix problems" does not always indicate to stop the assembly line each time a deviation occurs. Within Lean philosophy the goal is to make it right from the start and to secure that quality is fulfilled. Therefore, Andon is a great tool to visualize when something is about to happen or a call for assistant (Liker, 2004).

2.5.3 The five S's of Lean

Liker (2004) mentions that the 7th principle is about using visual control, so all problems come to surface but also to improve the flow. Visual control is defined as a communication device used at the workspace to show how work should be done but also if it deviates from the standard. It also helps the employees to see their own process. By using visual control, it gives information about where things should be, and the number of things that should be there, about standardized process of a task, the status of work in progress and many other information that can be critical to the flow. There are activities that eliminate waste that contribute to mistakes, defects and injuries in the workplace. These activities can be described as the five S's of Lean. The five S's are described in more details below (Liker, 2004):

1. Sort - all things are unnecessarily and do not contribute to any avail. This can be done by red tagging.
2. Straighten (orderliness) - put the things that are used often nearest operator, this is to avoid all sort of waste, such as unnecessary waiting times, having to stretch far for something and unnecessary transport.
3. Shine (cleanliness) - it must be clean in the workplace. This is to avoid damage or wear to the machines
4. Standardize (create rules) - the first three S's must become a habit. Therefore, a system must be created so that there is a follow-up. It can be done by having a checklist for every day or week, or a schedule.
5. Sustain (self - discipline) - Sustain the process so improvement of the five S's can be done.

2.5.4 New Technology

The way Toyota implements technology is very specific and precise. When new technology is introduced, the technology has been tested and experimented thoroughly by people within the company, in form of a pilot (Liker, 2004). This refers to the 8th principle by Liker, "*Use only*

reliable, thoroughly tested technology that serves your people and processes". The meaning of this is that technology must be evaluated and tested before implementation. The point is to ensure that the technology provides and supports the people, process, and values. Since one of the foundations of lean production is to work with continuous improvement. If the technology does not improve the current state, and if it does not benefit the process or operation, it would most likely not be applied (Liker, 2004).

2.5.5 Value and Cost

As mentioned by Liker (2004), value creation is often related to cost reduction in lean thinking and Hines et al., (2004) are also presenting the same statement. One of the principles of lean thinking is value. By shifting direction from shop-floor level focus on waste and cost reduction, to a more customer-oriented approach, where focusing on removing unnecessary activities and adding product-and service features (Hines et al., 2004).

According to Hines et al., (2004), by changing focus to customer value, there are two ways of value creation:

- By reducing/removing waste, wasteful activities, the associated costs within the business will increase the overall value to the customer.
- Another way to increase the value is to offer additional features/services that add value to the customer, e.g. short delivery time.

2.5.6 Criticism of lean

Lean thinking has developed and evolved during the years and this have created misconceptions, and therefore created criticism over time. The critics inherit from the lack of contingency, lack of human aspects, variability, and a narrow-minded focus on the shop-floor (Hines et al., 2004).

Lack of contingency

There is a misconception when it comes to implementing lean thinking in organizations. The focus of lean implementation has been on the shop-floor level, especially in the automotive industry. Companies try to get a competitive advantage with the help of lean but are focusing on a small part of the concept rather than the whole picture, which could give a more competitive edge if lean thinking is fully implemented (Hines et al., 2004).

Human aspects

The high pressure to the shop-floor workers is an aspect that is criticized. The critics are from Garrahan and Stewart in 1992 that studied a plant that had achieved the highest output of cars/week in Europe. They and another author named Williams view lean production as dehumanizing and exploitative. All the three authors however believe that lean is not only about tools and techniques, but mostly about the respect for people, motivation, and empowerment. Which is arguably the key elements for a long-term sustainable lean program (Hines et al., 2004).

Lack of strategic perspective

The lack of discussion of strategic level thinking compared to discussions about different tool and techniques are one the causes of criticism in lean thinking. This gap had resulted in a lack of sustainability when it comes to lean transformation and therefore created criticism (Hines et al., 2004).

Dealing with Variability

Coping with variability in lean production systems and supply chains has been criticized. As mentioned, previous by Hines et al., (2004) offering variety in products and services will create value to the customer, therefore it is important to be able to manage variability. However, critics mean that lean production system cannot cope with the demand of variety. Furthermore, the pull-system such as Kanban was criticized for being too inflexible. As a result of this, companies moved to more agile solutions, due to greater emphasis to deal with variability and flexibility in the supply chain (Hines et al., 2004).

2.6 Financial view of quality

A product can be described based on certain characteristics, such as reliability and durability. These properties have an indirect link to revenue. From a customer's perspective, there is a tendency to want to pay a higher price and increase its purchasing quantity if the product is of high quality, which can lead to the price being more adjustable. By offering customers a product of high quality, it can lead to customer satisfaction and customer loyalty. Increased customer satisfaction and customer loyalty can result in an increase in revenue (Ax et al., 2015).

2.6.1 Quality and profitability

According to Bergman and Klefsjö (2012) the concept of quality consists of two parts, "external quality" and "internal quality", they also describe how external and internal customers to the organization's various processes are experiencing the quality.

The relationship between factors that influence quality can be described with the help of figure 1 (Bergman & Klefsjö, 2012). Competitiveness can be increased by utilizing improved profitability and access to information. When quality in internal processes is improved, it results in the need for intermediate stocks and other reserves being reduced and, in this way, improvements can be implemented. When stocks are reduced, they release capacity, this released capacity can be used to increase production capacity and improve quality (Bergman & Klefsjö, 2012).

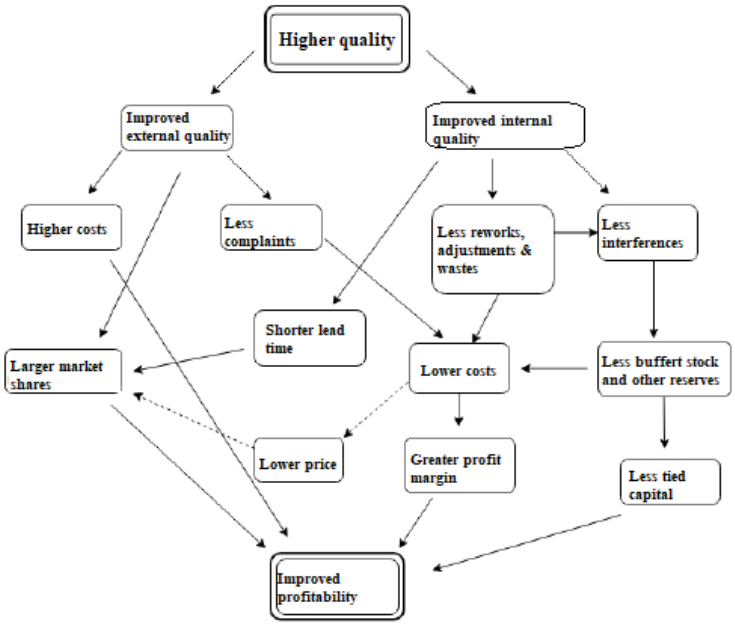

Figure 1: The figure shows the relationship between a higher quality and an improved profitability where both external-and internal quality terms are mentioned and how the external and internal customers experience quality (Bergman & Klefsjö, 2012).

By working with lean and striving for Just in time, it entails an expectation of a high internal quality, but also a hard work with suppliers' quality, in order to keep the rationalization of capital. The term Just in time stands for an endeavor to produce and deliver products in exactly the amount and at the time required (Jonsson & Mattson, 2016). Profitability can be improved through lower prices and probably increased market shares.

2.6.2 Traditional quality costs

A famous quote from Joseph Juran "the gold in the mine" refers to the association between cost and quality work. Since the time and work that requires to correct, and fix quality problems is equal to money. Juran states that companies are putting too much effort into quality shortage and this can be prevented if quality is assured at the beginning. Other influential persons within quality circuit agree with the statement from Juran but are pointing at other factors that lead to increased costs, in form as errors and scraps (Bergman & Klefsjö, 2012). The quality costs were divided into following categories from Juran:

- *Internal error costs* are caused by deviation from the original product or material that were identified in the company. For example, scraps and redoing are included in this category
- *External error costs* are costs caused by products that are detected by the customers after delivery. For example, complaints and warranty costs.

- *Control costs* are basically the cost for making sure that the requirements of products and materials are fulfilled that were agreed on. Control when receiving, during manufacturing and stock control are examples of control costs.
- *Prevention costs* are related to different quality actions taken within the development- and manufacturing process. Evaluation of suppliers and the growth of the staff are two examples of prevention costs.

These quality costs listed above are important to consider, especially internal error costs. These costs are easy to follow up and make comparison compared to external costs. Since it is hard to measure the costs for lost deals due to lost/lower trust from the customers (Bergman & Klefsjö, 2012). The authors also state that the internal error costs are approximately 40% of the total costs, therefore it would be beneficial to invest into preventing actions before they occur. Surveys show that the costs for quality shortage in the Swedish industry is between 10-30% of the organization's revenue (Bergman & Klefsjö, 2012). According to Bergman & Klefsjö (2012), the concept of quality cost is not based on the cost for quality, but rather for the lack of quality. The costs for redoing and compensation for defected products is the main factor.

2.7 Digitalization

In most industries, digitalization is currently one of the main forces for organizations and their strategic decisions making. When speaking about digitalization in the industry, smart manufacturing is the most common one and it refers to Industry 4.0 (Schumacher et al., 2018). The concept of Industry 4.0 is to connect and integrate value creation steps along the supply chain and to have a more flexible, sustainable, and efficient production operation (Machado et al., 2019). Digitalization and Industry 4.0 are connected and to be able to achieve the concept Industry 4.0, the requirement of investing in digitalization is an important step in the right direction, however according to experts within the area, one of the main barriers is the high investment cost (Schumacher et al., 2018). Furthermore, a study by Machado et al., (2019), state that most Swedish companies have taken the first step towards digitalization and have applied technical applications into their organizations. Although the importance of presenting possibilities and benefits, companies are still facing the same challenges, mainly lack of knowledge (Machado et al., 2019).

2.7.1 Correlation between Industry 4.0 and Lean Production

There is a correlation between lean production and Industry 4.0. Since Industry 4.0 is a concept that involves automated equipment and more digitalized work, critics believe that this will take away work, however researchers claim that this is not the case. Because Industry 4.0 requires individuals to get more specialized in certain skills (Tortorella & Fettermann, 2017). As mentioned previously about lean production, the philosophy aims to reduce waste, improving productivity and quality. The production system is mainly focusing on the human aspect, by emphasizing on involving and evolving employees within the organization. Tortorella & Fettermann (2017) state that Industry 4.0 will have an impact on lean implementation, by overcoming current obstacles and to become a successful implementation. Furthermore, lean production might be necessary for companies in developed countries for using digitalized technologies in production (Tortorella & Fettermann, 2017).

A study performed by Tortorella & Fettermann (2017) in Brazilian manufacturing companies shows that Industry 4.0 and lean production are connected. The study shows that the size of companies is not an issue when observing the association. With the urge to implement lean production and finding more efficient ways of doing business, companies will find new technologies in order to do that. In that case, Industry 4.0 will support and provide that, since the correlation between technology and human-based simplicity exist, especially in developed countries (Tortorella & Fettermann, 2017).

3. Methodology

There are a few approaches for collecting empirical data to get an image of the current situation, take measurements and provide facts and basis for the content of the study (Eliasson, 2018). Eliasson describes two methods, qualitative and quantitative. The qualitative method is used to get a deeper understanding of the study, which refers to observations and interviews. Quantitative method involves general data collection which is then summarized in an analysis (Eliasson, 2018). In this study, qualitative as well as quantitative methods will be applied, in order to answer the questions.

3.1 Data collection

Data collection can be divided into primary data, which includes the data collected on its own through observations and interviews at the company, but also quantitative study. There is also secondary data that includes data previously collected by others for purposes other than the report's (Eliasson, 2018). In this report, secondary data consists of information from the company's Volvo Trucks collection of quality problems.

3.1.1 Observations

An environment has been observed, in this case the assembly line at Volvo Trucks and this observation will be documented and analyzed. The observations performed included the whole assembly line called main line. The reason why the whole main line was included was to see the whole assembly process and understand each part of the line. However, the main focus was initially on part 7 in the area called Final Assembly 1 (see chapter 4 for further information) but changed to the entire assembly line in general. These observations were done in the early stage of the study to bring a broader picture and understanding of the current situation.

Deviation reporting is a crucial part at the production line, and it is important to highlight that. By observing the team leader boards that are located beside the assembly line, the previous day's deviations have been identified and summarized by one team leader for one part. Since there are several parts in each area, one team leader (out of 2-3) is doing this each morning. The deviations are mostly from QULIS but there are some that deviations that are identified via Audit. Audit is a sampling where a couple of units are randomly controlled before being sent to the customers.

3.1.2 Interviews

A common method used in data collection in qualitative research is interviews and the method may look different regarding the structure. Interviews in this context are considered as a conversation with a person about questions regarding a topic that is decided in advance. The purpose of this type of data collection is to provide important information from the employees, in this case the operators at the assembly line. The operators will be told in advance that they are anonymous, for ethical reasons. To increase the validity of the collected material, relevant and consequential questions should be asked in order to obtain detailed statements (Dalen, 2007).

In this case, a semi structured interview was used, which means that one person is interviewed one at a time and the number of interviewees is normally 5-10. In the selections of the informants, it is better to choose people who are as different from each other as possible, as it

gives a broader view (Hedin, 2011), hence it was decided to interview 6 team leaders with different rolls.
The interviews were set up in an untraditional way since the idea was to get a broader understanding of the current situation and therefore some of the questions were more general. By having this set up, the answers from the interviews were not steered into a direction, rather to a more open discussion. All interviews were recorded and those who were interviewed were selected based on recommendation from the management, since they have a good structure and understanding of their work according to Azrak. Furthermore, the interviews were booked in advance and held in a calm environment, in a conference room, and lasted around one hour. These conditionings were set to give the person the amount of time necessary to answer the questions without a hurry. The outcome of this gave the answers more credibility and understanding of their reality.

The interviews were mainly focusing on these questions, hence there were also supplementary questions depending on which person that was interviewed.

- Which department do you work at?
- How many stations and operators are you responsible for?
- How do you educate and certificate your staff?
- Are there covers for all variants in production?
- How do you handle deviations?
- What are the challenges on deviation reporting according to your opinions?
- Describe a normal day at work.
- Suggestions for future solutions on deviation reporting?

3.1.3 Secondary data

Volvo's deviation reporting system, Quality Information System (QULIS) has been used to gain secondary data and to complement data collection about the current situation. Furthermore, the secondary data from QULIS has been complied with observation and interviews to support analyzes in the thesis. Hence, this system contains lots of data that is not relevant to the purpose of the study, and therefore information about deviation reporting has only been used. Notice that this system is not adapted to the information needed to the purpose of the study and therefore complementary.

3.1.4 Literature study

The purpose with the literature study is to compile available information that is found around the area in a study using scientific publications (Bryman & Nilsson, 2011). For the study, the scientific method, abductive reasoning will be used. The method is a combination of inductive reasoning and deductive reasoning which means that during the study there will be movements back and forth between empiricism and theory. For this to be possible, it is important that the collected material is adequately revised and analyzed (Dalen, 2007). Examining information from previous studies and see how the area has been investigated, it can create significant arguments for the research area as it is supplemented with own thoughts and from other points of view and serves as support for the argumentation or the result presented (Bryman & Nilsson, 2011).

As an introduction to the work, an online course is conducted, the purpose of which is to ensure credibility in the literature studies through work with source criticism, academic integrity, and copyright management. Studies on the management of literature linked to the report and report writing have done in order to achieve academic quality and to lay a stable foundation for the study.

Part of the method is information retrieval and keywords that were used to search for literature are: *quality management in the automotive industry*, *Lean*, *Industry 4.0*. When it came to identify which literature to use, reading abstracts was the approach to determine if the literature is relevant. The literature research is to support the study with a theoretical framework and thus create a basis for the analysis. The information retrieval has been collected from digital databases such as the Chalmers Library, websites but also from books. Examples of books are *Kvalitet från behov till användning* by Bergman and Klefsjö from 2012, *Kvalitetsbristkostnader: Ett hjälpmedel för verksamhetsutveckling* by Sörqvist from 2001 and *Den nya ekonomistyrningen* by Ax, Johansson and Kullvén from 2015.

3.2 Quality of research

In order to avoid lack of credibility in this study, high validity and reliability is important. Validity is a concept that describe how well the measurements. the data collection, measure what is to be measured. Thus, the relevance in this context is whether the study is valid (Eliasson, 2018). High validity assumes that the study is based on a clear question and the collected data is also checked. Reliability describes how reliable the study is, i.e. that the same results can be obtained when repeating the implementation. For example, by measuring the most important variables in different ways, creating routines, and preparing the study well and controlling the collected data, reliability can be increased (Eliasson, 2018).

In order to increase the validity and reliability, the study is based on data collection from the interviews which makes the information relevant. The interviewees are team leaders, most of them were operators before, this emphasizes the importance of their knowledge of prevailing quality problems. One aspect that increases the credibility of the study is whether it can be generalized. In the context this has been achieved, partly through a wide selection of problems and that interviews were conducted with several different team leaders. This gives us a whole picture of what the reality looks like for the company, which means that results can be applied to other similar businesses.

4. Current situation

In this chapter the current situation of Volvo Trucks operations will be described. An overview will be given of how the company works and manages deviations. The current description has been built on the basis of tours around the assembly line (observations) and interviews.

4.1 Company description

The Volvo Group is one of the world's leading manufacturers of vehicles which include private cars, trucks, buses but also construction equipment. Volvo products are designed to create efficient transport and infrastructure. With the headquarter located at Gothenburg, the Group has 100 000 employees and production facilities in 18 countries with sales in over 190 markets. The group consists of 12 brands including Volvo, Volvo Penta, and Renault Trucks where Volvo Buses and Volvo Trucks are part of the Volvo brand. Volvo Group Trucks operations or Volvo Trucks Aktiebolag, is as indicated above engaged in manufacturing and industry in motor vehicle manufacturing. Volvo Trucks Aktiebolag develops, produces, and markets motor vehicles, spare parts, and accessories. The company also performs related services to the other operations. The main geographical markets, from largest to least sales, are Europe, Asia, and Africa.

Volvo Trucks at Tuve opened in 1982 and the plant has an area of 117 500 m^2. They work with customer adaptation, vehicle assembly, manufacturing of cabs, frames and completely knocked down (CKD) The term, completely knocked down means that the truck is disassembled into parts and then shipped to the customer so they can assemble. They supply frame members to their own production line and to Ghent, Kaluga and also to their knocked down (KD) plants. None of their trucks are alike the other, that is because of the customer adaptation they offer. More than half of the trucks produced at Tuve are highly adapted to meet specific customer requirements, according to Azrak it is likely 80 % of the produced trucks that are customer adapted. Completely knocked down involves packing truck component kits for subsequent assembly in one of their KD assembly plants. In order to get closer to their vision which is to be the most desired and successful transport solution provider in the world, they need to provide trucks with high quality, that is because of the customer's business is based around the trucks, which means they need to work 24 hours a week. The customers have also the opportunities to walk along the assembly line to see the process of trucks they ordered. At present, they have their own Volvo Production System (VPS), like most other organization, the idea originated from TPS and the lean production philosophy. However, an important factor to notice is that every organizations should design their own version of the TPS since TPS is not only a collection of tools and methods to use for management and production, but also a culture and philosophy. Therefore, the importance to design an own production system where the philosophy is connected to the company's visions and culture (Liker & Meier, 2006). Volvo Production System is the way to world class and includes continuous improvement, for example by raising the standard of their working methods step by step. One of their basic aims is to ensure that everything they do creates value for their customers. There are several stages before reaching the world class, these are listed below:

- VPS Foundation
- VPS Bronze
- VPS Silver
- VPS Gold *

- VPS Platinum
- VPS Diamond

**(Volvo plant at Tuve is currently at this stage)*

4.2 Production structure

The process for a complete built up unit, in this case the trucks, takes just over 6 hours, i.e. from the frame members to a finished truck. The production line is of a fishbone type with kitting and pre-assembly operations carried out in close proximity to main line. The main line is L-shaped and consists of 3 parts, base module, final assembly 1, final assembly 2, see figure 2 below. Every part consists of 2-3 teams, see figure 3. The assembly line is partly "stop and go", where the operator controls the movement of the truck. This is due to both ergonomic and safety precautions.

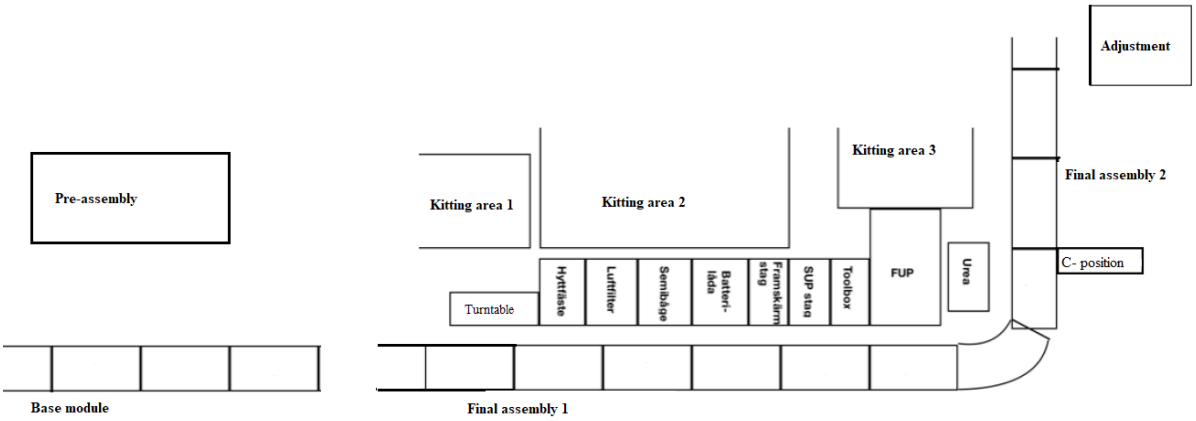

Figure 2: A simplified flow chart showing the layout of the production which includes main line, pre-assembly kitting areas and control station

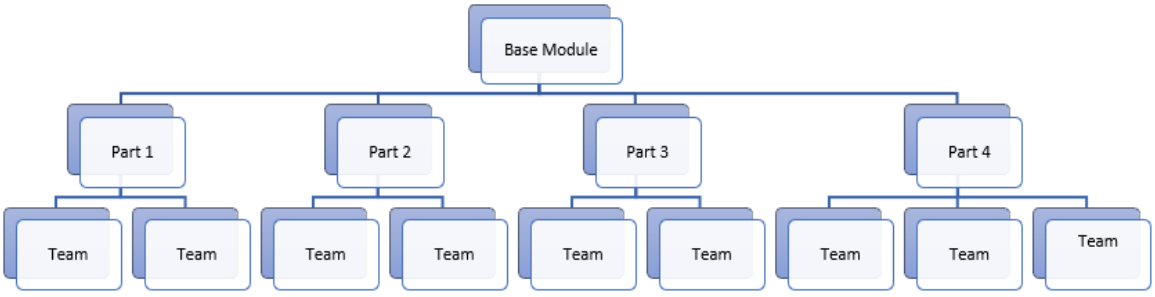

Figure 3: The structure of Base Module. The other departments such as Cab trim. Final assembly 1 & 2, End of line, have also similar structure as Base module.

4.2.1 Working instructions

Each team on the assembly line has either one or several pre-assembly stations. However, the working principles at the pre-assembly station are similar to the assembly line, where the operators follow a standardized sheet called Standardized Operation Procedure (SOP). The SOPs do not cover all the instructions to assemble the truck, only the basic steps, since the high level of variance of the trucks. As a result of this, assembly instructions (AI) are added to cover the remaining steps and details of the assembly. The AIs can be found at every station on the assembly and at the pre-assembly stations. The assembly instructions come in form as papers and are removed and refilled daily by a team leader each morning. From interviews and observations, the required time it takes to refill and remove the AIs for one team leader is approximately 30 minutes. Since the assembly line is divided into 13 parts, it requires 13 team leaders each morning to perform this work. Therefore, the estimated time spent on removing and refilling the AIs each day for the whole line will be 6,5 hours (0,5h x 13 parts = 6,5h). Moreover, the AIs are delivered and printed out each week by a supplier.

There are cases where AIs do not cover all work. Therefore, specialized operators called S-operators are introduced to perform operations that are not presented on the AIs. The S-operators mainly focus on heavy customized trucks and will assemble the trucks in between stations to limit the interference with the operators performing their tasks. However, from observations and interviews, interferences with S-operators and operators occur and can cause interruptions. Moreover, S-operators are usually well-educated operators that have worked several years within the company and have a wide overall knowledge of the mechanics of a truck. Hence, there are times when the S-operators lack coverage and knowledge of a truck, which increases the deviation reporting status.

4.2.2 Competency matrix

Every team leader aims to have at least three operators with expertise for all balances. This is done through job observations where the team leader follows a competency matrix to check what the operator can do. The aim is to do at least one job observation/day for each team leader. The competency matrix is based on the certification stages;

Competency matrix	
Stage 1: Watch and learn	The operator just follows and look at the work
Stage 2: Work along a supervisor	The operator starts to assembly partially with the help of the supervisor
Stage 3: Self-going	**The operator understands the basic of the station and is self-going**
Stage 4: Supervisor	The operator can now tutor and have a broader understanding of the station

Table 1: A simplified competency matrix at Volvo Trucks Tuve.

An operator must be certified in stage 3 in order to work at the balance by themselves. However, the certification of an operator is done differently depending on the team leader. There is no standardization when it comes to register a certification and how often it must be updated. The certifications are based on how much the operator understands the balance. Based on 24 questions about common errors, deviation, and severity. Then the operator will be observed on four trucks to see if they are capable to work on their own. Notice, that an operator that is not certified as stage 3 is not eligible to work at the balance.

4.2.3 Deviation management

In the current situation, operators register deviations with different severity that occurred daily. There is a deviation card that follows the chassis once it rolls out on the assembly line throughout the process. On the deviation card, there is information such as chassis number, which problem type, the problem owner, the one that reported, location etc., see figure 4 below. This information is later registered in a system called Quality Information System (QULIS). QULIS is a system for reporting deviations which are mainly identified during the assembly process or through Audit which means that the trucks are further checked for defects or other problems, so that it does not reach the customer (Volvo Group QULIS, 2020). Examples of deviations reported in QULIS are problems with unscrewed screws, failure of pipes to be clamped, faulty brackets, faulty hoses, and broken cables, all varying in frequency and severity. Operators report and register deviations in QULIS annually, however, these numbers do not reflect the whole truth, since the management and team leaders have mentioned that there are know that there are unrecorded deviations that have not been reported in QULIS, i.e. deviations that are easily fixed by an operator would probably not be reported at all. Therefore, the management approximates that the hidden numbers are around 10-15% of all deviations reported from last year.

Deviation card	Chassis number:				Location			
Person reporting:	Problem detail				Problem type			
Problem owner:	Pipe	Screw	Cable	Console	Not assembled	Incorrect assembled	Broken	undrafted
Comments/ deviation description								

Figure 4: *A simplified version of the deviation card used by Volvo Trucks. It comes with a picture of the chassis divided into parts in the complete deviation card, so it is easier to point out the location.*

The deviations can be divided into customer reported and own reported. Customer reported occurs when deviations are reported from outside a team responsible for the deviation. This involves the whole organization and also customers. Own reported deviation is when it is detected within the team. Volvo Trucks estimate that 75 % of the total deviations are customer reported.

Several team leaders have stated that they spend a lot of time with deviation management and that it is non-value-added work. They start the working day by reviewing the deviation card from the day before and then report in QULIS. As mentioned earlier in the introduction of this paper, according to the team leaders, it is time consuming to interpret the deviation card and re-address some deviations back and forth if needed.

According to the majority of the team leaders interviewed, they all agreed that the deviation reports were lacking in form of the data quality. With that said, the data registered on deviation cards do not always contain all data required. Since the deviation cards are written manually by an operator or team leader, the human factor is an aspect to consider. Most of them stated that the deviation card could be hard to understand and sometimes unreadable. Since majority of the time, the deviation card is not written by the same person that registers the deviation in QULIS. The risks for misunderstandings and own interpretations increase. Moreover, the lack of data quality can lead to incorrect registrations to different teams, which is time consuming just to figure out and address the deviation to the rightful owner. Furthermore, the communication between parts on the assembly line is done via voice calls.

The main line is divided into segments, BM, FA1, FA2 (see figure 2). These segments can be broken down into subparts and each part consists of 2-3 teams (see figure 3). From interviewing several team leaders from different parts of the site, every team leader on the assembly line states that it takes around 20-40 minutes each morning to register previous day deviations into a document. However, one team leader is responsible for their part's deviations, for example in BM, there are 4 parts and 10 teams. Therefore, it requires four leaders from each part to register the deviations address to them (see figure 3). Furthermore, operators that were working at the station where the deviation was reported at will also be registered. By registering the operators, feedback can be given to the operator and the traceability will be improved. These calculations lead to an average time of 30 minutes spent every morning and it is done by all 13 parts from the assembly line. As a result of that 6,5 hours/day are spent to register deviations from QULIS.

There are controllers at some stations, which is called the K-zone. These inspectors have specific points that they look at. They try to find all deviations and then log it into QULIS. It is also those who determine the severity of the various deviations and assume if the operators should have seen it. If it is a serious error, then they make an investigation and then set up a control station. If the error is not revoked after 12 weeks, then the k-zone can be removed, and a new k-zone can be added where required. Since there is not much space in the factory, the number of control stations is limited.

Difficulties experienced with reporting deviations to QULIS is that it is sometimes difficult to interpret what is on the deviation card and the words in QULIS are limited which means it is not possible to write the same thing as it says on the deviations card. According to the quality manager interviewed, many of the problems are related to trucks that are customer adapted.

5. Discussion

In this chapter the research questions will be answered and discussed. Discussions about sources of error will come at the end of this chapter.

5.1 The impact of the deviation reporting and possible improvements

Despite the high degree of the customer adaptation Volvo Trucks offer, they have succeeded quite well in reaching high quality in their products and satisfy their customers. However, the quality management can be improved. According to theory in chapter 2.2, a common problem is that there is a lack of coordination between the departments, which we can see in Volvo Trucks. In addition the team leaders having to interpret the work card and log the deviations into QULIS, they often have to re-address the deviations to the right departments and sometimes it happens to be discussions between these departments about who is the owner to the deviations. The current way of reporting the deviations that occur means that the quality management is not ultimate. This means, among other things, that the team leaders or the management do not have full control over the deviations, unknown deviations exist, and they affect the quality in its entirety. It will be difficult to make improvements if you do not know what the root cause is. One way to deal with such problems is to organize kaizen events where the focus is on the connections between the different departments.

Since the operators that have the best knowledge of what is happening at the shop level, it is good to arrange kaizen events involving them and focus on the quality circle. It is a good way to improve the quality because the problems are highlighted and employees together with the management can make proposals for solutions and discuss them together. This makes the workers feel involved in decisions that are made. In the interviews, it was emphasized that the operators could experience the work as monotonous and how it would have been better if they could take on a role with more responsibility. For example, one can have the responsibility to order gloves they use to assemble the truck, when it is out of stock at their station. By engaging them to do more and give them more responsibilities, it feels less monotonous and motivation of the operators increases.

These improvements also lead to a lower quality cost for the company. By doing the right thing from the beginning, the company can avoid internal costs, which in this case are deviations and rework. If the deviations decrease, the control costs also decrease because there will be no need for control stations along the production. It is easier to estimate the impact of the internal costs and control costs. That is because it is possible to calculate how much lost material cost the company than if they lose a customer. The authors Bergman & Klefsjö (2012) believe that a company should invest in preventing internal costs from rising, as these types of costs usually amount to 40 % of the total costs. The costs that can be avoided by Volvo Trucks should be invested in other activities that can bring value to the customer or the company.

5.2 Issues regarding deviation reporting

The way deviation reporting is performed today is not efficient. Since that a deviation card needs to be filled in manually by an operator or team leader and later reported into QULIS indicates that amount of work perform can be reduced by half. In other words, by reporting directly in a system instead of doing it manually on a deviation card, the risks of misunderstanding and miscommunication will be reduced. Since QULIS has already pre-

prepared choices of the deviations to choose from, the data quality from deviation reporting can be improved.

A challenge Volvo Trucks are facing is that the data quality from especially deviation reporting is lacking. According to serval team leaders, the data registered on the cards are often missing information. Due to the human aspect, where lack of time, stress, knowledge or just sloppiness/laziness that can make the data from a deviation card hard to understand. A solution is to have either a screen or a tablet on each station that is also used for AIs and SOPs. Not to mention, having a system such as QULIS where pre-prepared choices are available will most likely decrease the time for reporting and improve the data quality. In addition to this, a picture beside the deviation will increase the understanding significantly. Since an issue today is that it can be hard to address where the deviation occurs on the truck. By simply having an option to take pictures, will indicate where the deviations occur and that will ease the work for the involved ones. However, this requires a tablet with a camera on since a screen does not have that feature. By both having screens and a tablet (that the team leader uses), this way can reduce lots of non-value-added activities. Despite only having one tablet on every team, the way for operators to alarm the team leader is through the Andon system. Since this system is connected to the 5th principle from the Toyota Way, calling for help does not mean it is bad. After all, building a culture of stopping to fix problems is great, but reporting them is also necessary to improve quality. For instance, if a common deviation occurs frequently and is fixed by an operator and not reported. Then the management will not have that information and does not have any possibility to solve the deviation, since it will not be brought up to the surface. Again, it is the operators that will be affected by the situation. The reason being extra work and potentially deviation registered towards them, that might be wrong due to supplier's fault, etc.

5.3 Way of working

Currently, the operators are working with the help of SOPs and AIs in order to assemble trucks. Since the high degree of variants occur, each truck may vary from the previous one. Therefore, the importance of having AIs for each truck is necessary. Furthermore, having standardized processes to a certain extent, where the operators can perform their tasks and as a result of that eliminate waste that contributes to mistakes, defects and injuries. These activities can be described as 5S. Volvo Trucks are currently in the right direction when it comes to 5S. Their response to 5S is SOPs. However, the SOPs and AIs are not always covering all the tasks necessary to assembly the truck. This is an issue regarding the preparation department, but often tends to fall on the production line, mainly the teams and operators that get deviations reported towards them. In order to succeed at greater quality on the assembly line, all information must be provided correctly and cover all tasks. By visualizing all activities and the working areas, operators will have a better view on their own processes and therefore have a greater opportunity to perform. Hence, if not all activities are provided from the AIs, then the operators are set up for failure from the start.

5.4 Lean implementation

TPS is originated from Japan and is the fundamental of lean production. An important thing to point out is that TPS might not be suitable in all regions around the globe. Many people have tried to implement the same system but failed. The main concern is the culture differences, however there are other things that need to be considered, such as involvement of the whole organization. As lean production recommends, the way for a successful implementation of lean is to create an own culture and, in that case, an own production system.

The Toyota Way is based on 14 principles, which seems to be the ground for Japanese manufacturers. However, the culture differences between Japan and Sweden exists and as a result of that, the working atmosphere varies between these places. Comparing the current situation in Volvo Trucks to the Toyota Way, i.e., the first principle is about creating your own long-term philosophy. Volvo Trucks have created their own production system, VPS which is similar to TPS, but Volvo Trucks have adapted their philosophy to fit the culture and long-term goals for the organization. Volvo Trucks have created a ranking system, which is used by every site within Volvo Trucks association. This is a great way to work with goals and benchmarking with other affiliates around the world. On the other hand, Volvo Trucks are lacking in some of the other areas of the Toyota Way. For example, the 7th principle, referring to "*use visual control so no problems are hidden*" there are times when operators do not report deviations or problems on the assembly line. This is an example that might not occur in Japan. In other words, hidden problems will affect the whole organization and not only the operators at shop-floor level, but also management. With that said, by highlighting and bringing problems up to the surface, the chances to solve the problem will drastically increase. This will lead to improving the quality overall.

One of the main challenges with implementing lean production in an organization is to get all personnel involved. Since lean production is based on continuous improvement and is associated with creating value to the customers by removing or reducing non-value-added activities. A common misconception the workers believe in is that the lean production will lead to jobs removed. As a result of this, resistance will be created by the workers and that will most likely disrupt the implementation. However, that is not the case, since lean production is mainly focusing on the human being. By evolving the personnel daily and make them focus on continuous improvement, the goal is to develop the employers to the best version of themselves. Therefore, if certain positions are removed, those affected by this would be given new assignments or transferred to another place within the organization. With this in mind, a solution with implementing new things, especially in lean, one way is to have pilot projects. Volvo Trucks site at Tuve has a pilot plant where tests are being held at. By showing the critics the benefits with different changes instead of telling them is far more superior than words.

5.5 Involving the organization

One of the 14 principles presented by Liker (2004) is called Gemba. This principle is an important factor when it comes to understanding a situation, since you must go and see the situation by yourself. This quote is a good start for the management to understand the shop-floor level situation and their daily work. During the interviews, information brought up by team leaders indicated that the management is not often present on the assembly line and therefore lacking information about the whole operation. Gemba is one of the first steps to solve problems, due to observations. However, that is not the whole truth, since it requires a good capability to analyze and understand the situation to solve problems. In order to improve quality, the importance of involving the management is crucial. Changing the way of involving management into the daily work is one step on the right direction. Notice, that management receives data and information daily from production in form of numbers and documents. The deviations reported might not always be correct and can be inaccurate due to unrecorded deviations. Therefore, the importance of Gemba is essential for solving problems.

5.6 Non-value-added work

The assembly line combined with pre-assembly stations are currently working with tons of paper in form of AIs. The amount of time required to remove, refill, and sort these AIs is unnecessary according to several managers at Volvo. Since it requires around 6,5 hours daily, which is equivalent to almost an operator's working day (8h). This time is non-value-added time since it brings no value to the customer. Hines et al., (2004) stated that value is an important principle in lean thinking, where focusing on removing unnecessary activities and changing focus to customer value in order to create value. For example, reducing or removing the handling of Ais daily will reduce the cost and improve the environment aspect. The amount of papers used and removed every day are not sustainable.

Furthermore, another time-consuming activity performed by team leaders daily is collecting previous day deviations from QULIS and sort them in a report that will later be presented to a production leader. The average time it takes to create a report for a part is around 30 minutes. The process is similar to the AIs activities, where a team leader is responsible for all the teams in their part. This results in around 6,5 hours, since there are 13 parts on the assembly line. There are several solutions to reduce the time of this activity. By implementing a screen with a scanner on each balance, the operator can register themselves on the balance, which will be registered into the system. Hence, the operator needs to be certified to have access to the balance, which is based on job observations and later on a try-out. In that case, the system can register the operator and all trucks assembled within that time period. It requires that the operator has their keycard or employment number to register with. With this in mind, the system will be able to identify the operator during the time period. The team leaders do not need to sort the deviations to the rightful owner. Provided that the deviations have been addressed correctly, then the system will basically have a report ready for the team leaders the next day. As a result of this, the time can be reserved for other activities, such as job observation.

5.7 Digitalization at the assembly line

The AIs and SOPs are basically a bunch of papers that are removed, refilled, and sorted daily. These are necessary for the operators to assembly the trucks due to the high level of variability. The amount of papers thrown away every day can be viewed as unsustainable. On the other hand, these AIs are a part of the activities and in order to remove them, they need to be replaced. A solution is to digitalize the assembly line to a certain extent, especially the SOPs and AIs. Since AIs and SOPs are available at each station, replacing the papers involving SOPs and AIs with a screen could remove all the papers used currently. Screens could be used as a complementary, where both AIs and SOPs can be applied into. The amount of papers will be reduced drastically since AIs and SOPs will be integrated into the screen, which will create a clearer vision for the operators over their activities. Moreover, this system will connect all the papers and documents used today into a screen. By organizing all documents to a joint location, the risk of forgetting or losing them will be reduced. Furthermore, the time required each day to handle all AIs will be non-existent, due to the fact that the AIs would probably have been handled by the preparation department, that is preparing all AIs at the first point and is responsible to send the AIs to the supplier for printing and delivery. An additional benefit of digitalization is process improvements. The processes are connected to the quality management and the deviation reporting. The workload from reporting can be reduced by improved process improvements and the way of working at the assembly line too. Digital technologies can provide radical changes to the way of working, by the form of visual instructions and deviation reporting. As a result of that, this will go from a non-value-added activity to a value-added

activity for the team leaders, since they will not handle this activity and can focus on other activities that bring value to the customers.

Although moving to a more digitalized workplace, there are factors that need to be considered. As in TPS, the 8th principle is to use only reliable and tested technology that benefits the people and processes. This principle highlights the importance to test the technology thoroughly before implementing it. The key is to ensure that the technology provides and supports the people, processes, and values. Therefore, by having pilot projects in order to test the new technology, will eliminate most of the uncertainties and give a better understanding of the implementation.

In Volvo's case, implementing screens and tablets at the assembly line will contribute to many benefits for the company. However, these benefits are only theoretical and must be tested in order to see the actual results. One of the main reasons for companies to hesitate in digitalize and Industry 4.0 is the cost of the technology. In Volvo's case, every balance needs a screen if the AIs and SOPs will be removed. There are 206 balances that need screens. The cost of a screen with a scanner is quite high, which will result in a higher cost. This is a prime example of why it is so important to test the technology before implementation. Compared to the total cost for delivery of AIs annually is almost half of the cost for the AIs. So, within 2,5 years, the payback for the investment would be paid off. With this in mind, the cost from investing on screens, will have a greater return after two years in a financial aspect, compared to the current situation. However, this is based on the fact that the implementation works out as planned.

5.8 Different factors that affect quality

There are other factors that can affect the quality. Many times, when talking about the concept of quality, it is usual to think of product quality, but there is also process quality and it can be a cause for the quality of the product. For example, a problem in production may be due to another fault that occurred in another department that should make sure that the right tools and materials are in place when assembling the truck. For example, defects among the materials might exist already when it is delivered. This again leads to work that adds no value to the customer, which means they must spend time fixing the problem by contacting the supplier. This leads to extra costs and waste of time.

Another factor that also affects the quality of the product may be the preparation that the IT department handles. They have their own when preparing the sequence, what article number to use, instructions and more. It happens that the preparations are not perfect, and this causes errors in the assembly of the truck and thus poor quality.

Many companies that are working to eliminate defects in processes have used the six sigma concept and it has generated good results. Within six sigma there is the DMAIC method that is used to make improvements. Volvo Truck's way of working is similar to the method, but it would have yielded better results if they followed all the steps described by the method. It is common for people to start by solving a problem from behind and it can give good results, for example if a better tool is purchased, the work becomes easier and with better results. However, it is not a long-term solution and can entail frequent costs when the company needs to come up with new solutions. Instead, the company should focus on investigating what the basic problem is and from there start working on the DMAIC method.

5.9 Limitations

Based on the interviewers, we considered that the Base module was most suitable for us to gather information from. Questions regarding time spent on different activities were asked in the interviews. Then we took an average and assumed that it applies to the remaining departments. This may mean that the result for our calculations may vary.

Due to the limited time frame for the work, we only had the opportunity to interview team leaders, however no operators were interviewed which means that we cannot get a true overall picture of the production that would have been preferable.

Our discussions and conclusions are based on information collection and excerpts of data from QULIS. Since there are unrecorded deviations, it is not possible to calculate the cost of all deviations. A further source of error is that in the literature search we only found general theory about medium-sized companies in the automotive industry. Volvo trucks is a large company that offers a high variety of trucks, which means that the theory does not fully fit into the company.

6. Conclusions & Suggestions

In this chapter the answers to the research questions will be concluded, suggestions for quality improvement in the company are presented and future studies work.

6.1 Answers to the research questions

Deviation reporting affects quality management, if the reporting is performed poorly or incorrect it will result in a negative impact. Since deviation reporting requires the data quality to be on a certain level for other co-workers to cooperate, the human factor is one of the main factors involved. As presented, the deviation cards are either filled manually by an operator or team leader, the risks for errors and misinterpretation are high, due to either lack of time or knowledge. Furthermore, the deviation cards need to be registered at QULIS which is usually performed by another operator, often not related to the original operator that wrote the report. This affects the quality management on the assembly line. Another aspect that affects quality management is the deviations that do not get recorded at all. Both management and operators at shop-floor level have acknowledged the fact that there is a percentage of deviations that are unrecorded. This issue affects quality management indirectly since the deviations that are unrecorded will not reach the surface and therefore impact the quality management.

Quality management on the assembly line can be improved in several ways. One of the main solutions both the literature and Volvo Trucks urge is implementation of lean thinking/production. As for lean, the philosophy is based on eliminating waste, continuous improvement and focusing on the people. Since the operators are the main source of the assembly line, the importance of improving quality management starts with them, but it is important the whole organization has the same mindset and is involved in the process. Moreover, implementing digital solutions on the assembly line with screens and tablets can improve the quality management. By moving to a more paperless environment, benefits can be absorbed on the assembly line. Furthermore, there are requirements that need to be fulfilled for this to work. The workers need to be educated and trained in order for this to work. However, there has been a similar change at the site. At another line called Cab Trim at the plant, the production line has moved to a more digitalized set-up. By taking experiences and advices from coworkers at Cab Trim for education and training purposes, will help the start-up. However, combining both lean production and digitalization may be the optimal solution. Since both categories aim towards the same area, a joint goal might be the best solution for now.

6.2 Suggestions

There are several suggestions Volvo Trucks could do to improve their quality management. Firstly, create a culture for long-term goals and continuous improvement. Creating their own culture and philosophy that shifts to a quality mindset is crucial. As discussed, Volvo Trucks have already a production system (VPS) and this is a great step in the right direction. However, the quality outcome has not met the expectations, therefore moving to a more quality mindset in the whole company, alongside continuous improvements, could improve quality management overall.

Secondly, is to improve the communication between different departments that have impact on the production-flow. Since the company is divided in several departments, it tends to create barriers between them and can create a “we versus them” situation. This creates a mindset from departments to either shift or blame problems to another department, to save themselves. This

mindset must be removed in order to improve quality management within the company. Furthermore, the communication will improve if there are no barriers between departments or teams. Since communication is necessary for quality management and there are currently communication issues within different teams when it comes to deviation reporting. As mentioned previously, there are cases when operators do not have prerequisites to assembly the truck due to the high degree of variants. The preparation department is responsible for the AIs, which are the main instructions for the operators. This means that there is a correlation between these departments (production and preparation). However, there is another department that affects the organization. Customer adaptation (CA) is a department where customers order specific requirements for their trucks. Since Volvo Trucks pride themselves with their customized vehicles, they tend to fulfill the demands from the customer, if it is manageable. For instance, CA can promise a customer, but the preparation department might not have the knowledge for the demand. This leads to an uncertainty for the production line, since they will lack instructions for the assembly. To conclude, there needs to be better communication between departments and the cooperation needs to improve. Since the goals are joint, the problems occurring alongside the process will affect the company.

Thirdly, to give everyone in the company the opportunity to grow and progress at their work. Since the employees are the key to the company, it is important to give everyone the chance to develop. As in lean production, the most important part of a company is the employees. They are the one that will perform the work and keep the company running. Therefore, giving them the chance to grow is an essential factor for a company's success. This suggestion is connected to the second suggestion when the employees lack knowledge. By training and education, Volvo can give their employees the right prerequisites to succeed and continuously improve, but also learn. A recommendation is to encourage the workers to education and development. Hence, Volvo must give their employees the opportunity for education and development. Furthermore, give the employees the possibility to be more involved in certain decisions. Since the workers usually know the work, they perform the best, it could give an additional perspective alongside the management.

A suggestion that is correlated to the previous one is to change the mindset of the employees. For example, rewarding either employees or teams that are improving or finding improvements can change the mindset of the workers to continuously improve. However, the rewards are just a small part of the change. Since the employees will benefit from the improvements they are making, that will be their biggest reward in the long run.

A further suggestion is to focus on the deviations in more detail, to understand how and why they occur. By finding the root cause of certain problems can eliminate deviations and improve the quality management. Furthermore, the unrecorded deviations are a challenge for the management. By investigating the issue can possibly give a better understanding of the current situation and lead to reducing deviations.

An additional example is to compare other lines at the site. For example, Cab Trim that has already implemented screens at the production line. Comparing the two different lines and see what challenges the implementation at Cab Trim faced. Then again, there are differences between the lines but there are also similarities that can eventually help the main line.

In conclusion, the last recommendation for Volvo is digitalization. Implementing digital technologies can give great benefits at the assembly line. An essential benefit digitalization brings is an almost paperless environment. Additionally, the manual reporting system will be eliminated, and the reporting will be performed on either a tablet or a computer. Screens instead

of paper for assembly instruction will create a new way of working for the operators, by visual instruction. Another improvement that could benefit Volvo is to investigate in a digital system for deviation reporting. By integrating different systems in the company, for example, quality management systems and ERPs. This can lead to process improvements and the communication between different systems. Since most of the systems today do not cooperate with each other, a joint system between different systems could provide that. The chances of losing data between systems will most likely be zero to none.

6.3 Future studies and work

The current situation at Volvo Trucks is quite complex due to the high degree of variability and productivity. Since one of Volvo Trucks' core capability is to produce customized vehicles efficiently and in a high amount, the literature of the topic is limited to an extent. Most of the literature is based on small/medium size companies with a high level of variants. Therefore, for future studies it would be preferred to look at the large companies as Volvo with similar levels of variants. Furthermore, compare different Volvo Trucks sites around the globe and get their perspective of the topic. This will help to increase the reliability of the data and ease the work to give specific recommendations that could be applied into the assembly line.

For future studies and work, reducing the number of suppliers and not basing the decisions after the cost is a recommendation. Most companies around the world are choosing their suppliers based on the cost. However, lower cost might not always be the best choice, especially when it comes to quality. The price of the product is lower than others in the market, the trade-off could be the quality aspect. The time and effort required to fix or improve the products could in the end, result in a higher cost than the original cost from the supplier. By reducing the number of suppliers and base their decisions from a quality aspect, Volvo Trucks could improve the quality management. Moreover, with fewer suppliers, cooperation between suppliers and Volvo could be established. Creating a good relationship with suppliers can benefit both parts. In the long run, the cost could be reduced, and the quality would maintain. Observations were made that products from suppliers can impact the quality. Since several parts were already in bad condition, the quality management is affected. Therefore, investigating the suppliers in the future could be a possible option.

By performing a pilot project with implementing digital tools for deviation reporting, valid data could be abstracted from the pilot and give a better view of the outcome. Since, the cost of the implementation is a factor, showing that the project benefits the company can lead to a digitalization. The purpose of having a digitalized reporting system is to have greater control of the whole production line. Moreover, the way of working will also be considered in this case. On the essential benefit of implementing digital deviation reporting system is to eliminate non-value-added activities.

List of references

Ax, C., Johansson, C. & Kullvén, H. (2015). Den nya ekonomistyrningen. Stockholm: Liber AB.

Bauer, J. E., Duffy, G. L. & Westcott, R. T. (2006). The quality improvement handbook. Milwaukee: American Society for Quality (ASQ).

Bejlegaard, M., Brunoe, T. D., Bossen, J., Andersen, A.-L., & Nielsen, K. (2016). Reconfigurable Manufacturing Potential in Small and Medium Enterprises with Low Volume and High Variety: Pre-design Evaluation of RMS. *Procedia CIRP*, *51*, 32–37. https://doi.org/10.1016/j.procir.2016.05.055

Bergman, B. & Klefsjö, B. (2012). Kvalitet från behov till användning. Lund: Studentlitteratur AB

Bryman, A. & Nilsson, B. (2011). Samhällsvetenskapliga metoder. Malmö: Liber.

Cianfrani, C. A., & West, J. (2013). ISO 9001 : 2008 Explained and Expanded. ASQ Quality Press.

Dalen, M. (2007). Intervju som metod. Malmö: Gleerups Utbildning AB.

Eliasson, A. (2018). Kvantitativ metod från början. Lund: Studentlitteratur.

Goicoechea, I., & Fenollera, M. (2012). Quality management in the automotive industry. *DAAAM International Scientific Book*, 619-632.

Hines, P., Holwe, M., & Rich, N. (2004). Learning to evolve: A review of contemporary lean thinking. *International Journal of Operations & Production Management*, *24*(10), 994.

Hu, S. J., Ko, J., Weyand, L., ElMaraghy, H. A., Lien, T. K., Koren, Y., Bley, H., Chryssolouris, G., Nasr, N., & Shpitalni, M. (2011). Assembly system design and operations for product variety. *CIRP Annals - Manufacturing Technology*, *60*(2), 715–733. https://doi.org/10.1016/j.cirp.2011.05.004

Jens J. Dahlgaard, & Su Mi Dahlgaard-Park. (2006). Lean production, six sigma quality, TQM and company culture. *TQM Magazine*, *18*(3), 263.

Jonsson, P. & Mattson, S.-A. (2016). Logistik: läran om effektiva materialflöden. Lund: Studentlitteratur AB.

Juran, J. M., & De Feo, J. A. (2010). *Juran's quality handbook. [electronic resource] : the complete guide to performance excellence* (6th ed.). McGraw Hill

Liker, J. K. (2004). The toyota way: 14 management principles from the world's greatest manufacturer. New York: McGraw-Hill.

Liker, J. K. & Meier, D. (2006). Toyota way fieldbook. New York: McGraw-Hill.

Machado, C. G., Winroth, M., Carlsson, D., Almström, P., Centerholt, V., & Hallin, M. (2019). Indstry 4.0 readiness in manufacturing companies: challenges and enablers towards increased digitalization. *Procedia CIRP*, *81*, 1113–1118. https://doi.org/10.1016/j.procir.2019.03.262

Mateo, R. (2008). *The impact of absenteeism on the quality of assembly line production: The importance of a specialization requirement*. *18*(1), 49–69. doi: 10.1002/hfm.20095

Schumacher, A., Nemeth, T., & Sihn, W. (2019). Roadmapping towards industrial digitalization based on an Industry 4.0 maturity model for manufacturing enterprises. *Procedia CIRP*, *79*, 409–414. https://doi.org/10.1016/j.procir.2019.02.110

Nationalencyklopedin. (2020). *Kvalitetsteknik.* Retrivied from http://www.ne.se/uppslagsverk/encyklopedi/lång/kvalitetsteknik

Rojko, A. (2017). Industry 4.0 Concept: Background and Overview. https://doi.org/10.3991/ijim.v11i5.7072

Schumacher, A., Nemeth, T., & Sihn, W. (2019). Roadmapping towards industrial digitalization based on an Industry 4.0 maturity model for manufacturing enterprises. *Procedia CIRP*, *79*, 409–414. https://doi.org/10.1016/j.procir.2019.02.110

Tortorella, G. L., & Fettermann, D. (2018). Implementation of Industry 4.0 and lean production in Brazilian manufacturing companies. *International Journal of Production Research*, *56*(8), 2975–2987. https://doi.org/10.1080/00207543.2017.1391420

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECOMONICS
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2020
www.chalmers.se

CHALMERS
UNIVERSITY OF TECHNOLOGY