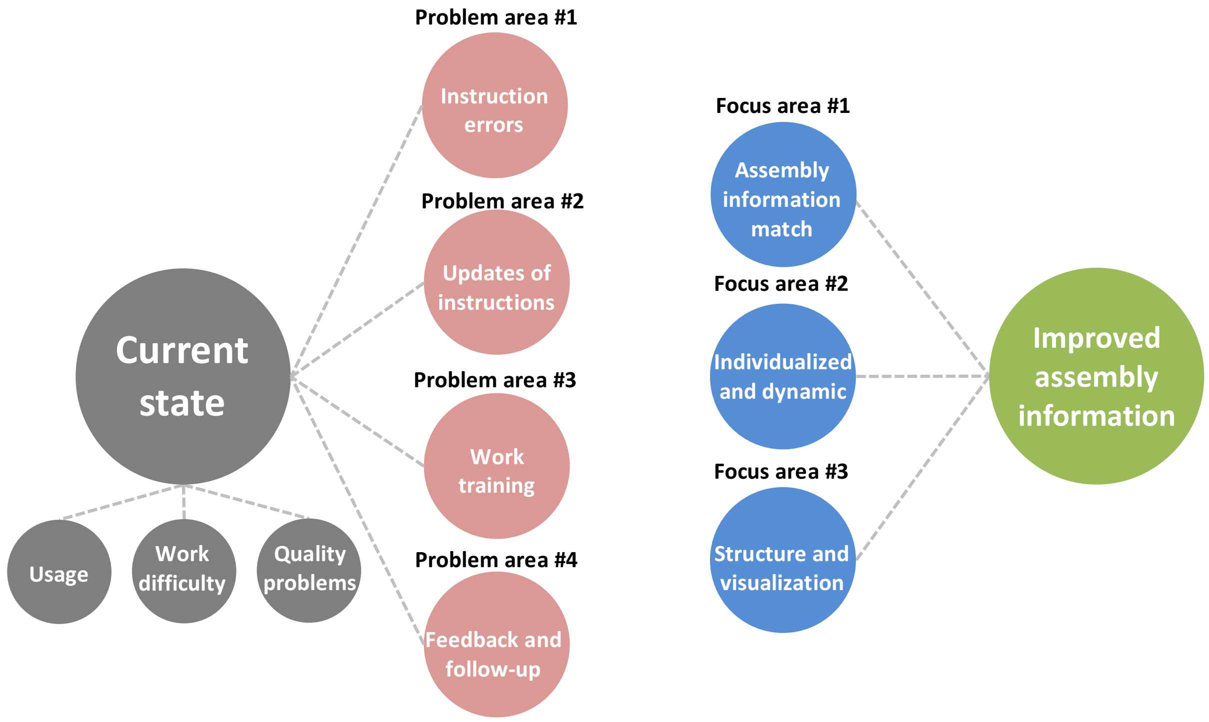


Assessment of Information Needs in Manual Assembly

A multiple case study that identifies current problem areas and focus areas for improvements at Volvo Group Trucks Operations

Master thesis in Quality and Operations Management

GUSTAF ERIKSSON
PONTUS JOHANSSON

Department of Product and Production Development
Division of Production Systems
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2017

MASTER THESIS REPORT

Assessment of Information Needs in Manual Assembly

A multiple case study that identifies current problem areas and focus areas for improvements at Volvo Group Trucks Operations

GUSTAF ERIKSSON

PONTUS JOHANSSON

CHALMERS

Department of Product and Production Development

Division of Production Systems

CHALMERS UNIVERSITY OF TECHNOLOGY

Gothenburg, Sweden 2017

Assessment of Information Needs in Manual Assembly
A multiple case study that identifies current problem areas and focus areas for improvements at Volvo Group Trucks Operations
GUSTAF ERIKSSON
PONTUS JOHANSSON

Supervisors: Magnus Åkerman and Sandra Mattsson
Department of Product and Production Development

Examiner: Åsa Fasth-Berglund
Department of Product and Production Development

Department of Product and Production Development
Division of Production Systems
Chalmers University of Technology
412 96 Gothenburg
Sweden
Telephone: + 46 (0)31-772 1000

Cover: The image visualizes the developed results of this thesis, where the current state, problem areas and focus areas are shown.

Chalmers Reproservice
Gothenburg, Sweden 2017

Assessment of Information Needs in Manual Assembly
A multiple case study that identifies current problem areas and focus areas for improvements at Volvo Group Trucks Operations
GUSTAF ERIKSSON
PONTUS JOHANSSON
Department of Product and Production Development
Chalmers University of Technology

Abstract

Large organizations are growing into even larger players, treating several markets around the globe, often leading to increase in product ranges in order to satisfy local markets. This has the risk of driving variation, cost, quality and productivity negatively in a manufacturing context and therefore need to be properly managed. The support towards the operators in manufacturing and manual assembly is generally based on assembly instructions, however, the usage tend to be low which has a negative impact on quality. Therefore, this thesis is focusing on assembly information needs with the goal of improving quality in manual assembly.

The thesis has gathered data through interviews with 25 operators, 7 additional engineering roles in the organization, literature studies and a comparison with a newly implemented information system to be able to answer the research questions. Firstly, general findings have been identified such as low and highly variating usage of instructions, the work difficulty is perceived as low, however, still experience quality problems. Secondly, the data analysis shows clear evidence that the information provided and the information need is inconsistent, which consequently has led to that the support towards operators as well as the perceived value of using instructions are too low, leading to quality problems in manufacturing. The assessment of the information needs has been divided into two main parts, current problem areas and focus areas for improvements. The identified problem areas consider: *Instruction errors, Updates of instructions, Work training* and *Feedback and follow-up* and are crucial to emphasize to get an effective and efficient way of working and hence support the assembly information system. Moreover, the developed focus areas consider: *Assembly information match, Individualized and dynamic information* and *Structure and visualization* and are vital to address in order to improve the assembly information and hence the quality in manual assembly. These focus areas can be seen as the drivers of an improvement of the assembly information, whilst the problem areas can be seen as the enablers of the improvements.

The results of this thesis have further been developed through perspectives of standardization to utilize synergetic effects as well of suggested requirement areas for a future assembly information system. This thesis has consequently revealed substantial improvement potentials in terms of assembly information, with the potential to improve quality in manual assembly. The thesis further contributes with a direction for the future based on information needs, which is important for organizations working in this kind of environment to manage product variety, quality, cost and productivity in a business environment characterized by high demands, customization and rapid changes.
Keywords: Assembly information, Assembly instructions, Quality, Manual Assembly, Operations Management, Requirements, Product Variety, Standardization

Acknowledgements

This master thesis represents the end of a long journey towards our master degree at Chalmers University of Technology as well as the hard work needed to reach where we are today. A lot of people have contributed to our thesis, both to the content as well as the process. Without you, we would not have been able to conduct this thesis, so we want to express our gratitude to the following people:

- First, we want to thank our supervisors at Volvo Group Trucks Operations, Pierre Johansson and Lena Moestam, who always been there to guide and support us throughout the whole thesis. Also, thank you for the opportunity for us to write our thesis in collaboration with Volvo and your team, it has been a pleasure!

- We also want to thank our supervisors at Chalmers University of Technology, Magnus Åkerman and Sandra Mattsson, for always challenging and supporting us in our process.

- Further, we want to send a big gratitude to our team at Volvo Group Trucks Operations for the hospitality and warmth. We have always felt welcome, so big thanks for all the moments together as well as your interest in our thesis.

- We could not have conducted this thesis without all the people that have participated and helped us throughout our thesis, so our sincere gratitude for all the help and interest you have showed us. Special thanks to all the participants in our interviews, our deepest appreciations.

- Lastly and most importantly, we specially want to thank our families, girlfriends and friends for being there for us, during this thesis, our studies at Chalmers and always.

We have finally reached the end of this journey and it has been an unforgettable and amazing time. We are now excited to see what the future will hold for us. Thank you all for making this possible!

Gothenburg, June 2017

Gustaf Eriksson

Pontus Johansson

Table of content

List of figures

List of tables

1. Introduction

This report considers the master thesis *"Assessment of Information Needs in Manual Assembly: A multiple case study that identifies current problem areas and focus areas for improvements at Volvo Group Trucks Operations"* conducted during the spring 2017. In this chapter, the topic and its background as well as the case company will be introduced. Also, the purpose, problem formulation, research questions and delimitations will be presented.

1.1 Background

The business environment of today is characterized by fierce competition on a global basis, with intense customer demands on customization in order to satisfy individual customer needs, also known as mass-customization (Hu, 2013; Oliinyk et al., 2015). As a result of this, companies are moving into new markets to find new customers and consequently unlock new revenues. When moving into new markets, companies significantly increasing the diversity of their product and service offerings to satisfy the specific market, leading to a significant amount of product variants (ElMaraghy et al., 2013; Fisher & Ittner 1999; Oliinyk et al., 2015). This diversification of the global production networks and increase in product variety leads to that the underlying processes are being heavily dispersed in the organizations (Egaña, Kamp, & Errasti, 2013; Johansson, 2016).

In the automotive industry and especially in the heavy-duty truck industry, the product variety has increased dramatically into an extensive number of variants. This development has also led to that the complexity in manufacturing has increased, since it can be defined as: "'*the interrelations between product variants, work content, layout, tools and support tools and work instructions*" (Mattsson, 2013, p. 61). For example, according to ElMaraghy et al. (2013) a common car can have up to 10^17 possible variants, which then are even higher in heavy-duty trucks due to the complexity of the product (Johansson, 2016). This variety can affect and drive quality, productivity and cost negatively if not properly managed (Fisher & Ittner 1999; Johansson, 2016). In order to gain competitive advantage and create synergetic effects in the global competition, companies need to work towards standardization of both products and processes to have a foundation for improvements (Liker & Meier, 2006). However, companies still need to emphasize local flexibility to ensure demands of local markets. This balance is of highest importance since companies need to consider the risk of increasing operational cost to be greater than the potential benefits of new revenue streams (Fisher, Jain, & MacDuffie, 1995).

Since 2001 Volvo Group has conducted several acquisitions, leading to a complex and global production network with a high level of product variety (Volvo Group, 2016). Therefore, Volvo Group has since 2013 initiated and been part of several projects (Enofe, 2017; Schwartzkopf, 2017; Johansson, 2016; Delin & Jansson, 2015) focusing on standardization of processes, where manufacturing engineering, preparation processes, manual assembly and instructions i.e. the assembly information system, have been the main area. Volvo Group together with other global organizations have experienced problems with diversity in the preparation process leading to several different standards for creating manual assembly instructions at factories in Sweden as well as globally (Delin & Jansson, 2015; Johansson, 2016). Because of this diversity, manual assembly instructions are not unanimous nor standardized, which make them harder to improve and enhance (Liker & Meier, 2006). Also, quality issues have arisen due to assembly errors or other assembly related issues, which have been shown to be one of the most significant quality problem in manual assembly, especially in environments with high product variety and high complexity (Johansson et al., 2016). Therefore, the question whether the instructions are valuable enough for the operators in order to secure the quality in this kind of environment has been raised. Thus, it is crucial to emphasize this issue to secure quality and potentially increase productivity and customer satisfaction, which are heavily correlated with quality (Bergman & Klefsjö, 2010).

1.2 Case company - Volvo Group Trucks Operations

Volvo Group is one of the leading producer of trucks, buses, construction equipment and marine engines with brands such as: Volvo, Renault Trucks, Mack, UD Trucks, Eicher, SDLG, Terex Trucks, Prevost, Nova Bus, UD Bus, Dongfeng, Sunwin Bus and Volvo Penta, where the business unit Volvo Group Trucks Operations (henceforth called Volvo GTO or only Volvo) encompasses the production of the truck brands as well as the production of engines and transmission (Volvo Group, 2016). Volvo was founded in 1927 with the aim of developing safe vehicles with high quality and the same year the first car was produced followed by the first truck the following year. Volvo grew into a group with a large organization, developing cars, trucks, buses, marine engines, construction equipment and components to aircraft. In 1999, the business area of cars was sold to Ford Motor Company and shortly after Volvo started to acquire several additional companies in various segments and markets to further strengthen the organization. Today, Volvo Group is a global organization, who employs around 100.000 people, with factories in 18 countries and operates in more than 190 markets with the goal of driving prosperity through transport solutions and to be the most desired and successful transport solution provider in the world.

1.3 Purpose

The overall purpose with this thesis is to study how to enable efficient preparation processes and secure an effective assembly process in the future. This thesis assesses the information needs in order to improve the assembly information and hence the quality in manual assembly. Further, the thesis will identify problem areas with the current working methods as well as develop focus areas that need to be emphasized to improve the assembly information in the future. Moreover, the goal of the thesis is that the result should be the basis for further work towards standardization and requirements of a new assembly information system.

1.4 Problem analysis and research questions

It has been shown that one of the most significant quality problems in manual assembly with high variety and complex environment are assembly errors (Johansson et al., 2016) leading to waste and additional cost. Also, previous studies argue for that there is a gap between the information presented and the information need, thus there are no common strategy of how assembly instructions should be managed (Enofe, 2017; Schwartzkopf, 2017; Johansson et al., 2017) Research, digitalization and new cognitive automation technology enables substantial improvements in how companies can create, visualize and present assembly information for operators in manual assembly (Fässberg & Fasth, 2011). Hence, there is great potential for improvements in how manual assembly information and instructions are utilized in global companies such as Volvo GTO. Thus, leading to the research questions with the purpose of investigating what kind of areas that would lead to a substantial leap forward in the development and ensuring sustainability in the future. Overall, the information needs must be assessed to facilitate this development and is therefore the main research question of this thesis. The information needs are divided into two main areas, problem areas and focus areas, where both are equally important to emphasize in order to improve the assembly information and hence the quality in manual assembly. The problem areas focus on the working methods of the current state and are important to identify to ensure support to the assembly information, stabilize the assembly processes and enable and sustain further improvements. The focus areas consider the direction of the development in terms of the assembly information that need to be conducted to make the improvements sustainable in the future. Based on the above reasoning, the research questions of this thesis are presented below.

RQ: *What are the information needs in the context of the assembly information that would improve the quality in manual assembly?*

- *a) What are the current problem areas in the context of working methods?*
- *b) What are the focus areas in the context of the assembly information?*

1.5 Delimitations

Due to the focus of this thesis, looking at future aspects, it will exclusively be a qualitative study in order to map the information needs, current problems and future focus areas in manual assembly. The thesis will only consider manual assembly since there are more errors in manual assembly and therefore higher potential to increase the productivity and quality as well as decreasing cost in this environment. The thesis follows a chain of other projects and theses and therefore, the same sample in terms of factories and use cases have been the scope of this thesis. Moreover, there will be no focus on the logistic aspects in this thesis since it would make the scope to big and time consuming to conduct. Since there exists an uncertainty about what kind of technology that will exist and be used in the future there will be no focus on technical solutions or detailed explanations on how the problems should be solved, instead this thesis will focus on presenting the information need, current problems and the focus areas for improvement.

2. Theoretical framework

In this chapter, the theoretical framework for this thesis will be presented based on the literature study that has been conducted. The areas that have been further studied are Standardization, Assembly information and instructions and Requirements Engineering and the relevance as well as the theory itself are described respectively.

2.1 Standardization

The result of this thesis has the aim of facilitating and supporting standardized work, both in terms of standardized work in the production line as well as supporting the standardization of the whole preparation process and the assembly instructions. Therefore, it has been included in the theoretical framework of this thesis, and will be discussed later in the report.

As described, the product variety and complexity in manufacturing are increasing since the business environment are moving towards mass-customization and globalization are driving this even further according to Oliinyk et al. (2015). This is further stressed by Hu (2013) who illustrates the evolution of the manufacturing paradigm, which can be seen in Figure 1.

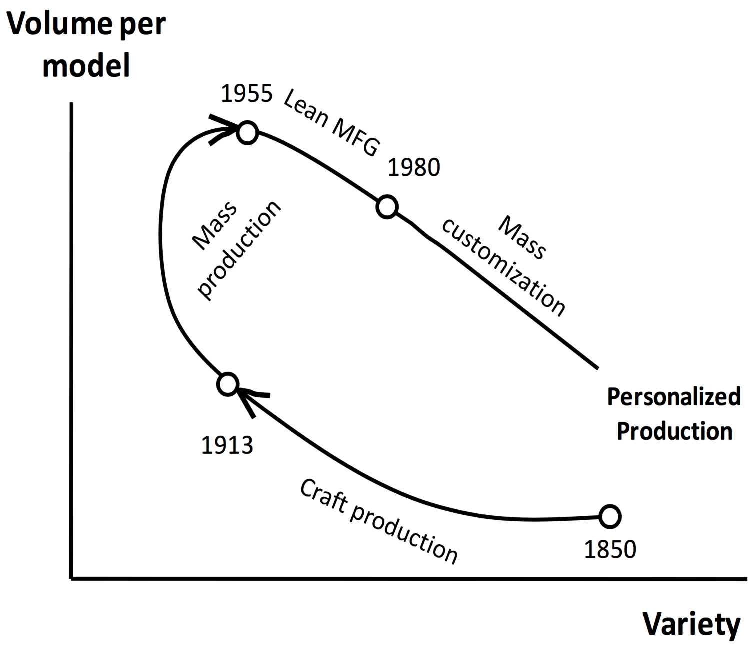


Figure 1. Illustration of the evolution of manufacturing paradigms by Hu (2013)

In order to manage this development, proper measures need to be emphasized and industry have made significant attempts to implement various philosophies, principles and tools (Marksberry, Vu & Hordusky, 2011). Standardization has been a successful methodology and thus a widely discussed topic, both in research and industry. Standardized work is heavily related to TPS (Toyota Production System) or also known as Lean Production and its philosophy, which was first coined and revealed for the world in the book "*The Machine that changed the world*" by Womack, Jones & Roos (1990). Although, standardization has been discussed and utilized already during the Taylorism (i.e. scientific management) in the early 1900s where the focus was to analyze the work to increase productivity and reduce lead times into one best way of organizing (Adler et al., 2009). However, the concept of standardization has evolved since then, especially during the development of TPS and Lean Production.

Liker & Meier (2016) describes standardization as the basis for process stability with the meaning to create consistent performance by defining and visualizing the best way of performing a practice. However, the important aspect is that the standardized work then acts as a foundation for improvements that are continuously changed and enhanced. This is also supported by Clarke (2005) who argue that that continuous improvement is being fostered if the standards are perceived as temporary instead of permanent. Standardization is according to Liker & Meier (2006) often confused with rigidness and controlling, which is wrong. Instead, the goal is to be the basis for creativity, learning, innovation, waste reduction, employee empowerment by defining new and better standards continuously as well as identifying abnormalities (i.e. variation) and eliminate it, which also is emphasized by Bergman & Klefsjö (2010) and by Marksberry, Vu & Hordusky (2011). A commonly used illustration of how standardized work are contributing to performance and continuous improvement can be seen in Figure 2. The performance is continuously being improved, whilst the standardized work ensures sustainability and a foundation for further improvements.

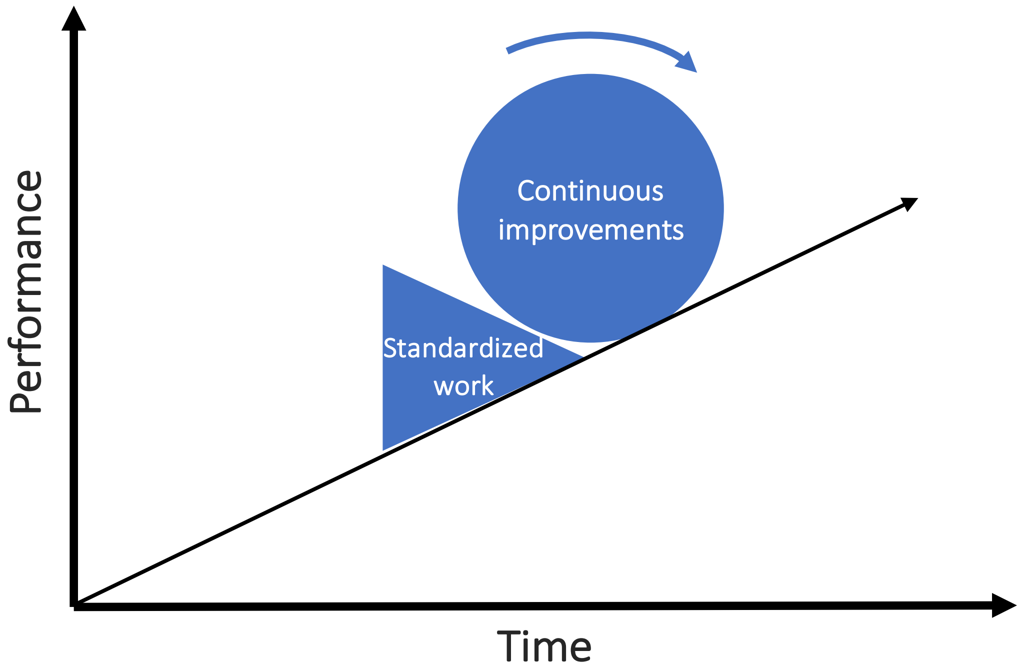


Figure 2. Illustrate how standardized work can be seen as the basis for performance and continuous improvements

Standardized work in a manufacturing context should be the responsibility of the operators, team leaders and supervisors, in order to enable and facilitate self-management, hence leading to higher motivation among employees, increased acceptance and encouragement of learning (Marksberry, Vu & Hordusky, 2011; Adler et al., 2009; Adler, 1993). In this environment, several factors are emphasized in the standardization such as: documenting and analyzing the work, visualize the current process, reduce variation and errors, increase productivity, measuring cycle times, ergonomics, ensure safety, improve training, enhance quality and most importantly, create a basis for improvements. The authors also describe that it is important to be responsive to the employees' needs to gain commitment and loyalty. In addition, Lander & Liker (2007) argues that standardized work can provide detailed and step-by-step explanations of the work tasks to specify e.g. sequence and cycle time. In order to facilitate an environment where standardized work and continuous improvement are successful, it has to be emphasized and promoted by upper management and then permeated throughout the organization, which is stated by Marksberry, Vu & Hordusky (2011). The authors further argue that the results of standardized work are a more consistent knowledge about current processes, simplified training, enhanced organizational learning as well as significant improvements in especially quality and waste reductions, but also in safety and cost. However, to have a successful implementation, Lander & Liker (2007) argues that it is essential to truly understand the philosophy (not only use the tools) and adjust it to fit the particular environment.

2.2 Assembly information and instructions

Even if an operator is experienced, there will be situations where new products or variants are assembled. When this occurs, they must rely on information from sources such as: experts, colleagues or assembly instructions, where the quality of the performance will depend on this information. Even though assembly instructions create a standardized way of working they are rarely used, since they often are containing too much information or of poor quality. The deficient assembly instructions can result in poor working procedures which in turn can lead to quality problems that create cost for the company, but it can also lead to problems for the workers in terms of frustration and unnecessary stress.

According to Rasmussen (1983) should information be arranged to fit an operator's cognitive process to optimize their performance. Osvalder & Ulfvengren (2009) further explain that a cognitive process is when people get aware of and process information, which involves memory and attention but also perception through vision and hearing. The cognitive resources are divided by the attention that helps the operator to focus on relevant information, and the memory helps them to store the information but also to make sense of it (Clark, Nguyen & Sweller, 2006). It is further explained by Garnier (2004) that the working memory consist of the short-term memory, it is active when working and processes the information a operator need to perform their work.

The designing of information can according to Agrawala et al. (2003) be divided into two areas, planning and presentation, that are important to consider when creating assembly instructions.

Planning
To make it easier to perform the assembly, by making the work more intuitive, the sequence of operations should be planned and placed in a suitable sequence. Agrawala et al. (2003) present two different theories of how the assembly can be planned, where the first one is grouping and hierarchy of parts. All parts are of difference significance for the finished product depending on their importance and function for the product. All parts included in a product can be arranged by their hierarchy and grouped by its function, the parts that are grouped should all be assembled in the same sequence. The second theory is hierarchy of operations, when the parts are grouped out of significance, it will affect the significance of different assembly operations as well, which also can be placed in different hierarchy levels (Agrawala et al., 2003). It is mentioned by Agrawala et al. (2003) that when planning an assembly procedure, parts of low significance are combined with parts of high significance. The reason for this is to make it easier to understand the assembly task.

Presentation

Information should be easy to understand and therefore should the presentation support the understanding. It should be easy to follow the instructions and the information should be presented step-by-step instead of everything at once (Agrawala et al., 2003). Osvalder & Ulfvengren (2009) further stress the fact that information needed in assembly, especially the information that is often used, should be easy to find and access. Therefore, should also information be presented physically close to the operator. The connection between different information sources can be strengthened through visual aids such as: arrows, typeface, lines and equal colors (Osvalder & Ulfvengren, 2009). Garnier (2004) mentioned that by using informative and clear headings, operators can get help to locate needed information for their task. Further, by presenting information through more than one source, e.g. paper and pictures, the understanding for the operators can be increased and therefore also the performance. Osvalder & Ulfvengren (2009) express the fact that objects, if they are similar, can confuse the operator which can be solved by highlighting differences, further they also mentioned that to prevent confusion and to make it easier for the operators, the instruction should be designed consistently. As a complement, the presentation of information should be consistent since it would reduce reading time and the time it takes for the operator to understand the information (Inaba, Smillie & Parasons, 2004). It is according to Li, Cassidy & Bromilow (2013) advantageous to have realistic pictures that show both the main object and details to communicate the right information.

2.2.1 Design Principles for Information Presentation

In order to create instructions that are cognitive ergonomically to use with high usability, *Design Principles for Information Presentation,* also called DFIP, has been created by Fast-Berglund & Mattsson (2017). DFIP contains of six steps that by using them, the amount of information should be kept to a minimum without affect the information, it should also make it easier to handle several different variants of components. The steps of DFIP are presented below.

1. Choose a work task in the workplace

When choosing a task, its relevancy should be considered together with if the improvement is needed and feasible to conduct.

2. Identify and support active cognitive processes in each sub-task

Depending on the activity that an operator is going to perform, he or she needs support that is matched to the activity. In order to know how the support should be designed, the processes are divided into three groups:

- Intuitive processes - these processes are activated through signals, e.g. traffic lights, and they are used in regular assembly.
- Reasoning processes - these processes are activated through a combination of inputs e.g. sound and sight. These processes are used in problem solving and in order to support them, all relevant information should be available for the operator.
- Rule-based processes - are used for both intuitive and reasoning processes. A rule-based process is when rules or patterns have been created before and now are activated through signs, e.g. certain picture or tool.

3. Analyze tasks based on how the operator perceives the work environment

Investigate how the operator perceive the work, what is complex and if all needed information is presented. This analysis can include aspects such as:

- Information flow - how is the information flow and where is the information placed.
- Work environment - how does the work environment look like and are there things that can disturb the operator.
- Standardized work - if standards exists, are they maintained and followed.
- Time management - how is the work planned and do the operators have enough time to do their job and recover when working.

4. Analyze tasks depending on cognitive limitations

Since there exist limitations in the cognition, the information should be reduced and simplified in order to make it possible for the operators to remember the information. It is also important to show the differences between different parts and to inform the operator when new parts are introduced, which can be done by using clear descriptions with numbers, arrows and magnification. Everything, from pictures to text, that are presented should be clear so it cannot be interpreted wrong.

5. Analyze tasks depending on individual differences and needs

Because all people are different from each other, it is crucial to consider individual needs when it comes to e.g. hearing, height and color vision. It can be divided into three different groups:

- Physical conditions - include things that are connected to operators physics e.g. height hearing and which hand the operator use.
- Individual request - specific requests given by an operator on things such as music, lights or when they access to the information/instructions and much more.
- Gamification - investigate if the work can include competitions to increase the performance or make the job more satisfying for the operator.

6. Analyze tasks depending on placement of information content and carrier

To increase the usage of information in an assembly environment it is important to make it easy for the operators to use it and therefore should these aspects be considered:

- Content placement, important information should be placed in the upper left to bottom right diagonal and less important information in the opposite diagonal.
- Additional information carriers, in order to support memory can pictures be added. There should not be too many information carriers and those that exist should be up to date.

2.2.2 Availability, usage and importance of data in assembly instructions

Earlier research done by Enofe (2017) and Schwarzkopf (2017) within the area of information at Volvo GTO, which also has been performed at Plant A (Cab & Vehicle assembly), Plant B (Engine assembly) and Plant C (Transmission assembly) demonstrates which information that is available and used by an operator so that they can perform the work in a correct and good manner. It also shows the difference of how important various information is perceived by operators and engineers.

Enofe (2017) and Schwarzkopf (2017) states that there is too much or insufficient information in the assembly instructions at Plant A, which uses SPRINT as assembly instruction and an example of this can be found in Appendix C. As can be seen in Table 1, they further explain that parameters such as: *Truck Type, Sequence Number, Serial Number, Assembly Line, CI (Core Instruction), C1, C2, Emballage (Emb), Use Point (UP) and Time Study* are not necessary and thus does not add any value for the operator when performing an operation at the line. The parameter *Work Instruction* which gives the operators information about the operations in form of text and pictures are not either used as much as it could, it is 100% available but only used 58% of the time, the reason for this is according to Enofe (2017) and Schwarzkopf (2017) that they contain inadequate information.

Table 1. Enofe (2017) and Schwarzkopf (2017) visualize the availability and the usage of different kind of data.

		A			B			C		
Parameter	**Type**	**Available**	**Used**	**GAP**	**Available**	**Used**	**GAP**	**Available**	**Used**	**GAP**
Product ID	Digital/Physical	1,00	0,92	0,08	0,50	0,50	0,00	1,00	0,33	0,67
Work Instruction	Digital/Physical	1,00	0,58	0,42	0,50	0,00	0,50	1,00	1,00	0,00
Part Name	Digital/Physical	1,00	0,92	0,08	0,75	0,25	0,50	1,00	0,00	1,00
Part Number	Digital/Physical	1,00	0,88	0,12	0,75	0,25	0,50	1,00	0,67	0,33
Quantity	Digital/Physical	1,00	0,80	0,20	0,75	0,25	0,50	1,00	0,33	0,67
Lamp	Pick-2-Light	0,04	0,04	0,00	0,50	0,50	0,00	1,00	1,00	0,00
Part Number	Pick-2-Light	0,04	0,04	0,00	0,25	0,00	0,25	1,00	1,00	0,00
Part Name	Pick-2-Light	0,04	0,04	0,00	0,25	0,00	0,25	1,00	0,33	0,67
Quantity	Pick-2-Light	0,04	0,04	0,00	0,25	0,25	0,00	-	-	-
SOP	SOP	0,80	0,52	0,28	0,75	0,75	0,00	1,00	1,00	0,00
Truck Type	Physical	1,00	0,04	0,96	-	-	-	-	-	-
Sequence Number	Physical	1,00	0,00	1,00	-	-	-	-	-	-
Serial Number	Physical	1,00	0,00	1,00	-	-	-	-	-	-
Assembly Line	Physical	1,00	0,00	1,00	-	-	-	-	-	-
CI	Physical	1,00	0,00	1,00	-	-	-	-	-	-
VDM (Variant Driven Module)	Physical	1,00	0,40	0,60	-	-	-	-	-	-
C1	Physical	1,00	0,00	1,00	-	-	-	-	-	-
C2	Physical	1,00	0,00	1,00	-	-	-	-	-	-
Emb (Emballage)	Physical	1,00	0,00	1,00	-	-	-	-	-	-
UP (User Point)	Physical	1,00	0,00	1,00	-	-	-	-	-	-
Time Study	Physical	1,00	0,00	1,00	-	-	-	-	-	-
Comment	Physical	1,00	0,76	0,24	-	-	-	-	-	-

Both Plant B and Plant C uses a digital assembly instruction, the MONT system. According to Enofe (2017) and Schwarzkopf (2017, there exist a big difference between Plant B and Plant C since the latter use the *Work instruction* all the time, whilst Plant B newer use it. They further explain that the reason for this is due to the fact that they are forced to use it in Plant C, it is more accessible than in Plant B, see Figure 3. Moreover, it is also low usage of the parameters *Part Name* and *Part Number* in Plant C which according to Enofe (2017) and Schwarzkopf (2017) depends on the high amount of Pick-to-Light systems.

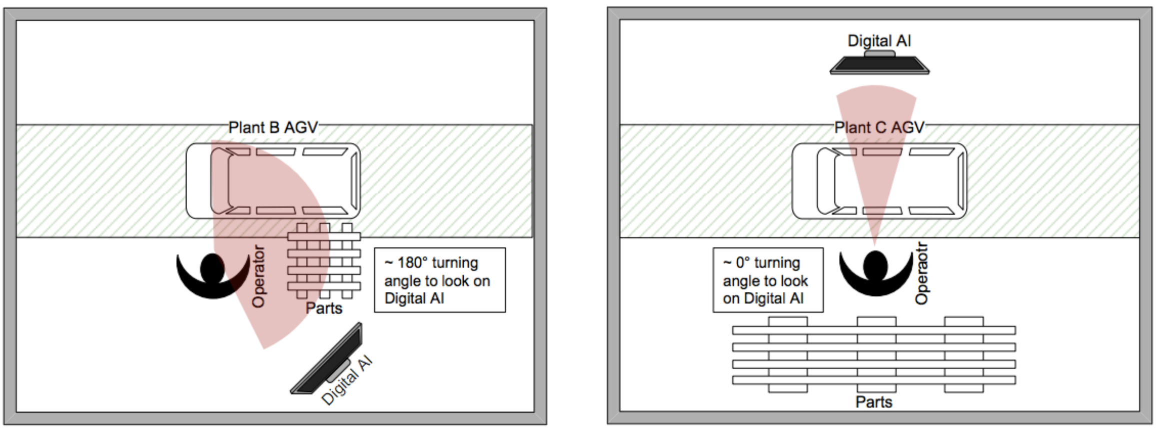


Figure 3. Schwarzkopf (2017) illustration of the layout of workstations in Plant B VS Plant C.

According to Enofe (2017) and Schwarzkopf (2017) are the *Part Name* perceived more important for the operators, which rate this parameter as a 4,36 on a scale of 1-5 whilst the engineers rate it as a 1. As can be seen in the Table 2 it is the other way around for the *Part Number* which the operators rate as a 3,56 whilst the engineers rate it as a 4,60. They further explain that the *Part Name* is seen as to be enough information for the operators to locate that part and the *Part Number* is only support information. The high importance for engineers are due to the fact that the *Part Number* is used in order to locate the part in the manufacturing preparation system. Table 2 also shows that the engineers perceive the SOP (Standard Operation Procedure) as more important than the operators, which according to Enofe (2017) and Schwarzkopf (2017) is due to the fact that the operators did not use instructions to find additional information, instead they asked someone else to gain information, which also applies to the other factories as well.

Table 2. Enofe (2017) and Schwarzkopf (2017) visualize the importance of data for operators and engineers.

		A			B			C		
Parameter	**Type**	**Operator**	**Engineer**	**GAP**	**Operator**	**Engineer**	**GAP**	**Operator**	**Engineer**	**GAP**
Product ID	Digital/Physical	4,68	5,00	-0,32	5,00	1,00	4,00	2,33	1,20	1,13
Work Instruction	Digital/Physical	3,16	3,60	-0,44	3,50	3,00	0,50	4,33	3,60	0,73
Part Name	Digital/Physical	4,36	1,00	3,36	2,33	1,80	0,53	1,00	3,20	-2,20
Part Number	Digital/Physical	3,56	4,60	-1,04	2,33	2,40	-0,07	2,33	2,80	-0,47
Quantity	Digital/Physical	4,12	1,80	2,32	2,33	3,20	-0,87	1,33	4,40	-3,07
Lamp	Pick-2-Light	5,00	5,00	0,00	5,00	5,00	0,00	5,00	5,00	0,00
Part Number	Pick-2-Light	1,00	5,00	-4,00	1,00	1,00	0,00	5,00	5,00	0,00
Part Name	Pick-2-Light	5,00	5,00	0,00	1,00	1,00	0,00	2,33	3,00	-0,67
Quantity	Pick-2-Light	5,00	1,00	4,00	1,00	5,00	-4,00	-	-	-
SOP	SOP	3,40	5,00	-1,60	5,00	3,00	2,00	3,33	5,00	-1,67
Truck Type	Physical	1,16	1,40	-0,24	-	-	-	-	-	-
Sequence Number	Physical	1,00	1,00	0,00	-	-	-	-	-	-
Serial Number	Physical	1,00	1,00	0,00	-	-	-	-	-	-
Assembly Line	Physical	1,00	1,00	0,00	-	-	-	-	-	-
CI	Physical	1,00	1,00	0,00	-	-	-	-	-	-
VDM (Variant Driven Module)	Physical	2,60	3,40	-0,80	-	-	-	-	-	-
C1	Physical	-	-	-	-	-	-	-	-	-
C2	Physical	-	-	-	-	-	-	-	-	-
Emb (Emballage)	Physical	1,00	1,00	0,00	-	-	-	-	-	-
UP (User Point)	Physical	1,00	1,00	0,00	-	-	-	-	-	-
Time Study	Physical	1,00	1,00	0,00	-	-	-	-	-	-
Comment	Physical	3,72	3,80	-0,08	-	-	-	-	-	-

2.3 Requirements Engineering

The information needs, identified problems and focus areas for improvements that are presented in this thesis can be seen as a foundation for requirements for a future developed assembly information system. It is therefore important to emphasize and present theory about Requirements Engineering in this thesis to be able to discuss the relevance of the result. In this section, the general and fundamental theory about this topic will be presented.

Requirements Engineering are growing in importance as the complexity in product, processes and systems increases and customers being more demanding. Hull, Jackson & Dick (2011) argues that requirements are the foundation for every new development project, whether it's hardware or software, by identifying the needs from the all stakeholders such as users, customers, suppliers, developers and business and hence being the basis for how the product or system are being developed. However, the requirements for a project can be many, diverse, not clearly defined from stakeholders, and possibly even conflicting, and the true challenge is thus to sort, prioritize, manage changes and find solutions in order to satisfy the stakeholders. Hull, Jackson & Dick (2011, p. 2) explains the importance of having proper requirements as: "*It is like setting off on a sea journey without any idea of the destination and with no navigation chart. Requirements provide both the "navigation chart" and the means of steering towards the selected destination.*". Further, they also state that according to a study, requirements are the solely most important factor for projects' success as well as the reason of failure if not properly managed. Therefore, it is vital to emphasize on requirements in an early phase of all development project to ensure the quality and sustainability of the product or system to get it right the first time (Bergman & Klefsjö, 2010). The definition of a requirement as well as requirements engineering that are being used in this thesis are presented below:

"***Requirement****: a statement that identifies a product or process operational, functional, or design characteristic or constraint, which is unambiguous, testable or measurable, and necessary for product or process acceptability (by consumers or internal quality assurance guidelines).*" (Hull, Jackson & Dick, 2011, p. 6).

*"**Requirements engineering**: the subset of systems engineering concerned with discovering, developing, tracing, analyzing, qualifying, communicating and managing requirements that define the system at successive levels of abstraction.* "(Hull, Jackson & Dick, 2011, p. 7).

During a project, there are requirements in all stages and levels of the development. A common view upon the process of creating requirements at the different levels as well as conducting the development project as whole can be seen in Figure 4.

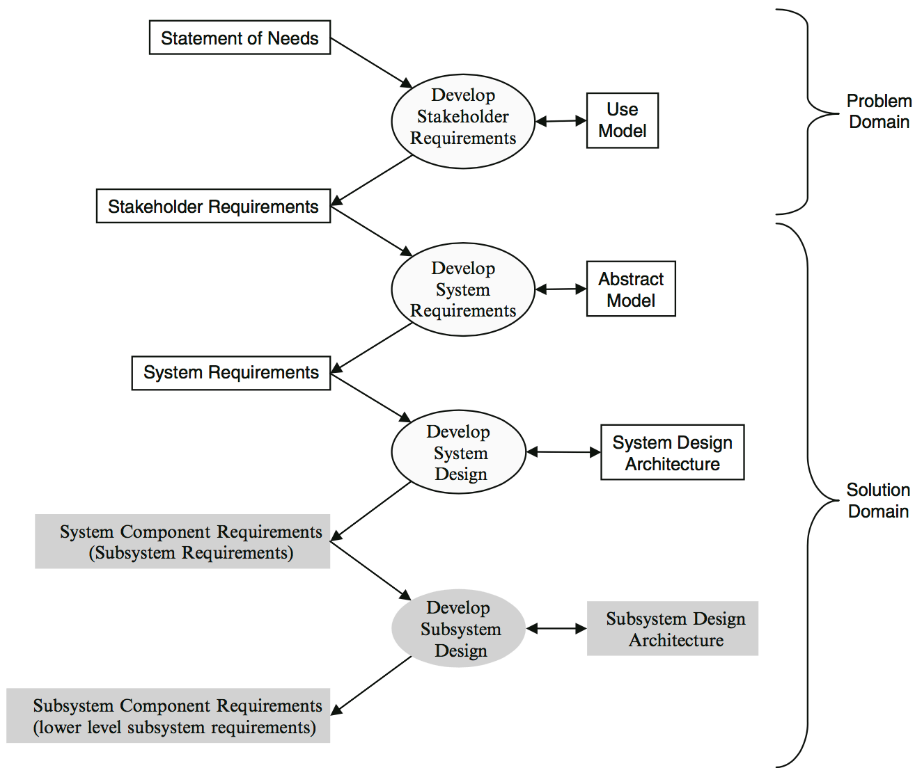


Figure 4. The process of creating requirements at different levels throughout the development project provided by Hull, Jackson & Dick (2011).

Hull, Jackson & Dick (2011) describes that the ovals represent the processes, actions or steps taken, the data/information that is read or produced is represented by rectangles and the arrows symbolize if the information is read or produced. More generally, the first step "Develop Stakeholder Requirements" is emphasizing the problem domain, meaning to understand the problem and identify the stakeholders needs before starting to design solutions, which are emphasized in the rest of the steps. For example, the stakeholder requirements are developed in the first step and are based on the statements of needs. It also interacts with the use model by producing and reading information before handing over the created stakeholder requirements to the next step. Further, then the process continues by creating system requirements, system design with system component requirements and then creating several and iterative subsystem designs with their respective subsystem requirements before creating the final solution.

Writing requirements that are clear and tangible is one of the most crucial parts (Chung et al., 2013). The main balance needed to be emphasized when developing requirements documents are the balance between readability and processability (Hull, Jackson & Dick, 2011). The requirements should be readable, easy to understand and in context, however, they need simultaneously to be sufficiently processable, precise and technical to be able to take actions upon them. Firstly, the requirements document needs to be structured in a logical way. Generally, according to Hull, Jackson & Dick (2011, p. 79) the following factors need to be considered to get a proper structure:

- *Minimize* the number of requirements
- *Understand* large amounts of information
- *Find* sets of requirements relating to particular topics
- *Detect* omissions and duplications
- *Eliminate* conflicts between requirements
- *Manage* iteration (e.g. delayed requirements)
- *Reject* poor requirements
- *Evaluate* requirements
- *Reuse* requirements across projects

There are two main categories of requirements that need to be emphasized, which are functional and nonfunctional requirements. Chung et al. (2013, p. 6) describes functional requirements as:

"*A system/software requirement that specifies a function that a system/software system or system/software component must be capable of performing.*" and non-functional requirements as:

"*[...] a software requirement that describes not what the software will do, but how the software will do it.*" and it can e.g. consider performance, external interface, design constraints and quality. Hence, the difference is that functional describes what the system should do and nonfunctional describes how the system will do it.

Further, the requirements can be classed both as key requirements that are non-negotiable as well as requirements that are desired based on importance. Also, different target values can be stated such as mandatory, desired and best values and the language of the requirements need to be consistent throughout the requirements document (Hull, Jackson & Dick, 2011). For example, word differences such as "shall", "should" and "may" indicate different prioritizations among the requirements. There are several ways of writing requirements based on factors such as if they consider capabilities, constraints, periodicity or any other kind of requirements, but one way to structure them is presented below:

The **<stakeholder type>** shall be able to **<capability>** within **<performance>** of **<event>** while **<operational condition>.**

3. Methodology

In this chapter, the methodology of the thesis is presented in terms of research strategy, research design and research process. Also, the chosen methodology for data collection and analysis will be presented. Finally, the steps taken to ensure the research quality as well as the ethical considerations are explained.

3.1 Research Strategy

The two main applied research strategies are quantitative and qualitative research (Bryman & Bell, 2015). Quantitative research focus primarily on numbers, historical data and testing of hypothesis and theory in contrary to qualitative research which instead emphasize on words and to generalize theory. This thesis has been structured with the qualitative research strategy and consequently had an inductive approach due to that the primary data in the thesis will be qualitative, mainly in terms of interviews. The inductive research approach has been chosen since it is most suitable when the research is focusing on combining theory and data from the real world in order to develop general findings and new theory (Bryman & Bell, 2015). Also, this approach allowed the thesis to follow the direction of the findings and be explanatory.

The benefits with qualitative research are the possibility to on a comprehensive and in-depth level, understand the social setting that is being researched, meaning the processes and peoples' knowledge and opinions (Denzin & Lincoln, 2000). However, qualitative research tends to lead to an extensive amount of data that can be hard to analyze, which demands more emphasis on the data analysis (Easterby-Smith, Thorpe & Jackson, 2012). Since this thesis focus on how to improve the assembly information, assessing the information needs and to identify current problems and focus areas there are no numerical or historical data, which lead to that the qualitative research strategy has been chosen.

3.2 Research Design

The thesis is designed as a multiple case study and is according to Bryman & Bell (2015) a preferred and common way of conducting research of this type. Denzin & Lincoln (2000) means that case studies are preferable when studying phenomena with generation of theory as a result. Also, the findings can be generalized to other cases, however, it is important to emphasize that cases only can be generalized to similar cases in an equal environment and are not applicable to all kind of environments. The multiple case study design allows the thesis to analyze how different factories at Volvo GTO are utilizing manual assembly information and the assembly instructions as such to get a comprehensive view of Volvo GTO as well as creating new theory within the field. Also, the multiple case study design has been chosen since the focus of standardization and creating synergies across factories are essential in this thesis.

3.2.1 Use Cases

The multiple case study consists primarily of interviews at the case factories in order to collect qualitative data. The data collected during the case study will be used to understand the current state and its problem areas, to be able to develop focus areas for improvement and finally, to be able to assess the information needs in manual assembly.

The cases included in this thesis are the following three factories at Volvo GTO:

- Plant A - Cab & Vehicle assembly
- Plant B - Engine assembly
- Plant C - Transmission assembly

These cases have been chosen to represent the main production plants and components of the truck production. Also, to broaden the scope to make the findings more comprehensive to the operations of Volvo GTO as well as to make it more theoretically relevant in additional contexts in operations management. In these factories, 13 use cases (i.e. production stations) have been selected where six are in Plant A, four in Plant B and three in Plant C. Further, these use cases have been chosen to scope the thesis but still include the main types of truck assembly activities, where there is general improvement potential. These general truck assembly activities are:

- Media Routing
- Equipment controlled assembly
- Hidden assembly
- High component variety
- Hole pattern recognition
- Clamping
- Consoles
- Riveting

In Table 3, the environment of each case is presented in terms of volume, variation (product range), cycle time and the primary instruction media. Each category is ranked according to a low-medium-high scale and in the instruction category, the primary media in this plant is presented. An example of the instructions can be found in Appendix C for SPRINT and Appendix D for MONT.

Table 3. Presents the environment of each of the cases included in this thesis based on volume, variation, cycle time and primary instruction media

Cases	Volume	Variation	Cycle time	Primary instructions media
Plant A	Medium	High	High	Paper (SPRINT)
Plant B	High	Medium	Low	Digital (MONT)
Plant C	High	High	Low	Digital (MONT)

3.3 Research Process

The thesis has been structured and divided into three main parts: the *preparation part*, the *data collection part* and the *analysis part*. However, more in detail about the steps taken in the thesis can be seen in Figure 5. The first part contains the three first steps. The first two steps focused on to get an introduction and understanding about the topic, the problem formulation, connected projects and the organization of Volvo Group and the third step prepared the data collection part. The interviews have been planned in terms of structure, content, questions and what kind of data that is needed to answer the research questions. The next part has been the data collection part and all the needed data for this thesis has been gathered in this part. The steps taken in this part has been conducting, documenting, interpreting and coding interviews, as well as conducting additional interviews with additional roles, comparison with Volvo Penta and the literature review. Finally, the analysis part of the thesis could be initiated. In this part, the remaining steps has been conducted, where the focus has been to structure, cluster, analysis and visualize the data to be able to develop the results in terms of information needs, problem areas, and focus areas for this thesis.

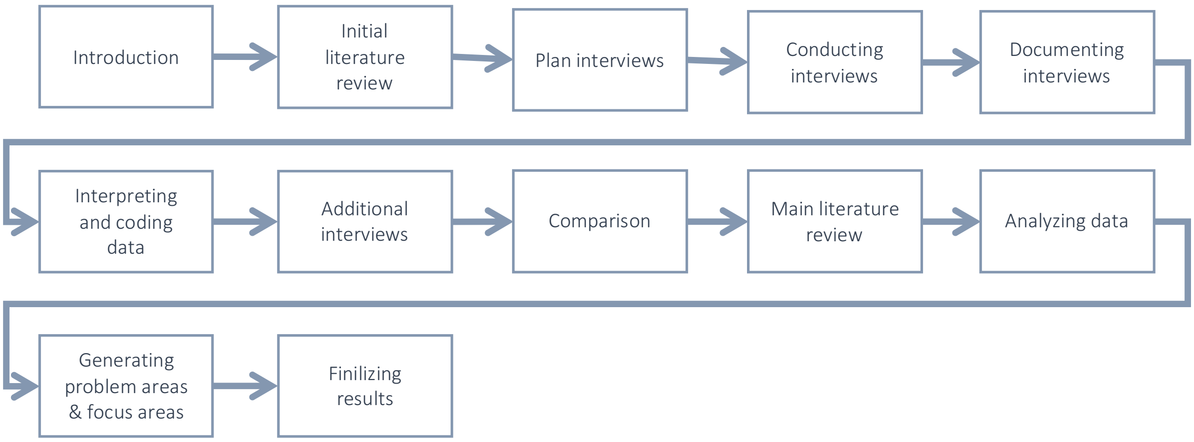


Figure 5. Illustration of the flow and steps taken in this thesis

The main research questions in this thesis as well as the sub questions has been answered during the analysis part based on the data gathered in the preceding part. Firstly, the identification of current problem areas has been emphasized followed by the development of focus areas, which consequently led to the assessment of the information needs in order to improve the assembly information and hence the quality in manual assembly.

3.4 Data collection

One of the main steps in this thesis has been the data collection. This has been conducted primarily through literature studies and interviews, which are further described below.

3.4.1 Literature study

Bryman & Bell (2015) suggest a five-step method, which this study has been performed according to, where the first step has been to study reports, articles and books that are connected to the stated research questions in order to create a comprehensive understanding about the researched topic. Also, internal documents will be studied to understand how Volvo GTO functions today, to create an understanding about the organization. While reading these documents and articles, notes have been developed where connections between keywords (e.g. manual assembly, manual assembly instructions, quality, assembly information, product variety, requirements, standardization, design for information presentation, instruction design) and the research questions have been made. During the fourth step literature that is relevant for this thesis has been searched for on electronic databases such as Google Scholar, Scopus and Chalmers library. In the fifth and last step, the abstracts and titles of found articles and books has been examined to check its relevance for this thesis. This literature study has then been used to contributing with input and to strengthen the results (Easterby-Smith, Thorpe & Jackson, 2012).

3.4.2 Sampling

The sampling for the interviews has been conducted using the theoretical approach advocated by Bryman & Bell (2015) for qualitative research and grounded theory analysis. Theoretical sampling is when the researcher jointly collects, code and analyzes the data in order to decide which data that needs to be collected next and whom to interview to get hold of that data, to develop an emerging theory. This is done until theoretical saturation is reached, which is defined as when the new data collected no longer gives new understanding or dimensions to the emerging theory (Bryman & Bell, 2015). Theoretical sampling has been used since this thesis had a clear starting point, to find the problems of the current state, information needs and focus areas for future improvements of the assembly instructions, and personnel using these instructions has been easy to identify. The first interviewees have been chosen because they had a lot of knowledge about the use cases included in this thesis. After analyzing the first interviews, it has been established what data that are missing and where to find it, which has been the direction of the following interviews. The number of interviews held at each case varied depending of the number of use cases at the different cases, and have been performed with a mix of different roles, which is explained further in section 3.4.3.

3.4.3 Interviews

In order to gather qualitative data for this thesis regarding e.g. information needs, current problems, focus areas, assembly instructions and production quality, several interviews have been conducted. There are different types of qualitative interviews e.g. unstructured, semi-structured and structured interviews, however, the semi-structured approach has been chosen because it allows the interviewer to guide the direction of the interview, but still gives the interviewee opportunity to go off tangent, which gives the researcher valuable insights in what the interviewee finds important or not (Bryman & Bell, 2015; Easterby-Smith, Thorpe & Jackson, 2012). Hence, the semi-structured interviews have been the main type of data collection used in this thesis.

A semi-structured interview is as explained above flexible. Before the interview, the researcher prepares an interview guide, which is a document that guides the researcher through the interview. It contains a set of predetermined questions whose task is to guide the interviewee through the interview, and to make sure that the discussion helps to answer the stated research questions for the thesis (Bryman & Bell, 2015). The approach of semi-structured interview has been chosen since this thesis is trying to capture how the quality in manual assembly could be improved by mapping the problems with the assembly information today and how it could be developed. By using this approach, the operators and engineers allowed to express their own opinion about this topic. To start of the data collection, unstructured interviews have been used to get knowledge about the organization and production. As mentioned are the semi-structured interviews used as the main data source with the aim of answering the research question. They are used to build a current state of how the assembly information are used today by the operators, but also to capture how they would like to use it in the future. The interviews have been conducted with personnel from three different manufacturing sites in Sweden and at different use cases (i.e. production stations). Also, to get a holistic perspective the interviews have been conducted with personnel from different levels in the organization, such as: Operators, Manufacturing Technology Specialist (MTS), Local Technology Specialist (LTS), Technology Manager, Production Technicians and a director of Process & IT. However, the focus in this thesis has been emphasized on the operators. The number of interviews conducted are shown in Table 4 and the interview guides used for the interviews are presented in Appendix E for operators and in Appendix F for the engineering roles**.** The Interviews have been held until theoretical saturation been reached and a theory had emerged through analyzing and combining the results of each interview.

Table 4. Shows the number of interviews performed with operators and additional engineering roles.

Role	Number of interviews
Operators	25
Engineering roles	7

As encouraged by Bryman & Bell (2015), the interviews have been conducted with two interviewers. This is advantageous because, when the interview has started one focus on taking notes and the other can lead the interview. The interviewer taking notes can also observe the interviewee to capture expressions and body language that can help to interpret the answers. It is also allowed for the same interviewer to intervene if the interview is going too far of topic. The use of two interviewers is also beneficial since it creates opportunities for discussion during the interviews, and this often leads to a greater understanding of the interviewees opinions. All the semi-structured interviews have been recorded and the recordings have then been used to extend the notes taken during the interviews.

3.5 Data Analysis

According to Bryman & Bell (2015), coding is the starting point in an analysis of qualitative data. Coding is when the interview data is broken down and grouped together where answers are similar, so that conclusions can be drawn. Firstly, the original notes from the interviews have been complemented through listening on the recordings again to ensure that all interesting data has been captured. The data from each interview has then been coded as soon as possible after the interview to ensure the understanding and quality of the collected data. With the results from the coding, different kind of concepts and groups of facts have been created and later used to create different kinds of categories, thus describing the main takeaways from the data collected from the operator interviews. This consequently led to the development of the thesis results and the answers to the research questions. This process is illustrated in Figure 6. This analysis method has been used for the operator interviews, whilst the interviews with production technicians, technology manager, MTS, LTS and Director Process & IT has been used in order to strengthen the data and are therefore presented in Appendix B and later used in the discussion to support the results and to contribute with additional perspectives. The data from the comparison has been analyzed and used in the same manner and can be found in Appendix A.

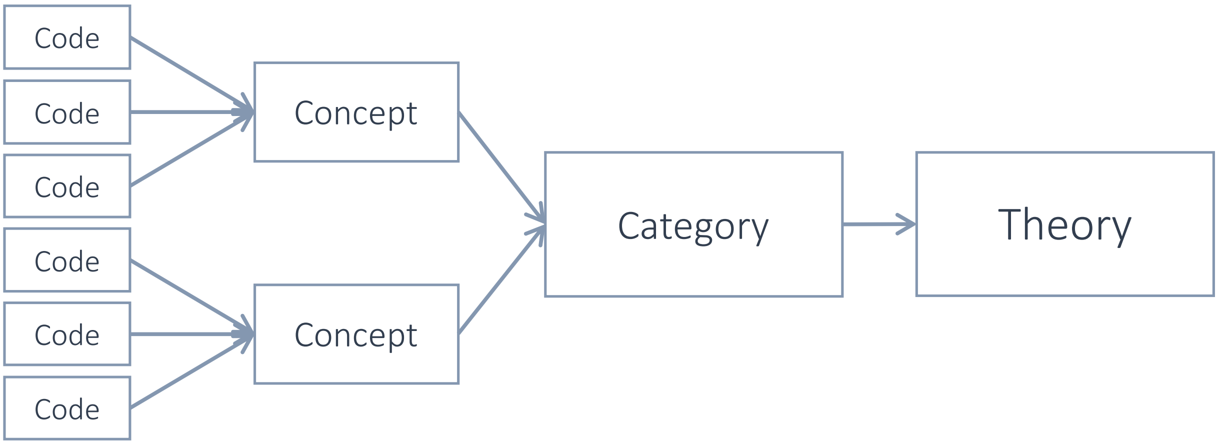


Figure 6. Conceptual illustration of how the data has been analyzed from codes to theory in the thesis.

To support this process, a tool called Affinity Diagram has been used, which is one of the seven quality management tools. According to Bergman & Klefsjö (2010), this is a successful tool when handling large extent of verbal data in order to organize it and to get the above mentioned structure with codes, concepts and categories. The first step has been to write down the data from the interviews on post-it and put them on a board. It is important that the meaning of the data is clear so the group understand it, otherwise it is allowed to add or rephrase the note. The next step has been to relate the data to each other and then group equal data together. When this is done, a heading to each group has been written to summarize the content in the group. It is possible to iterate this process with the headings, meaning to create categories of the groups that belong to each other. Also, it is possible to continue and draw arrows to represent relationships as well ranking to be able to prioritize. An example of the structure of an affinity diagram is shown in Figure 7, which is based on the model in Bergman & Klefsjö (2010).

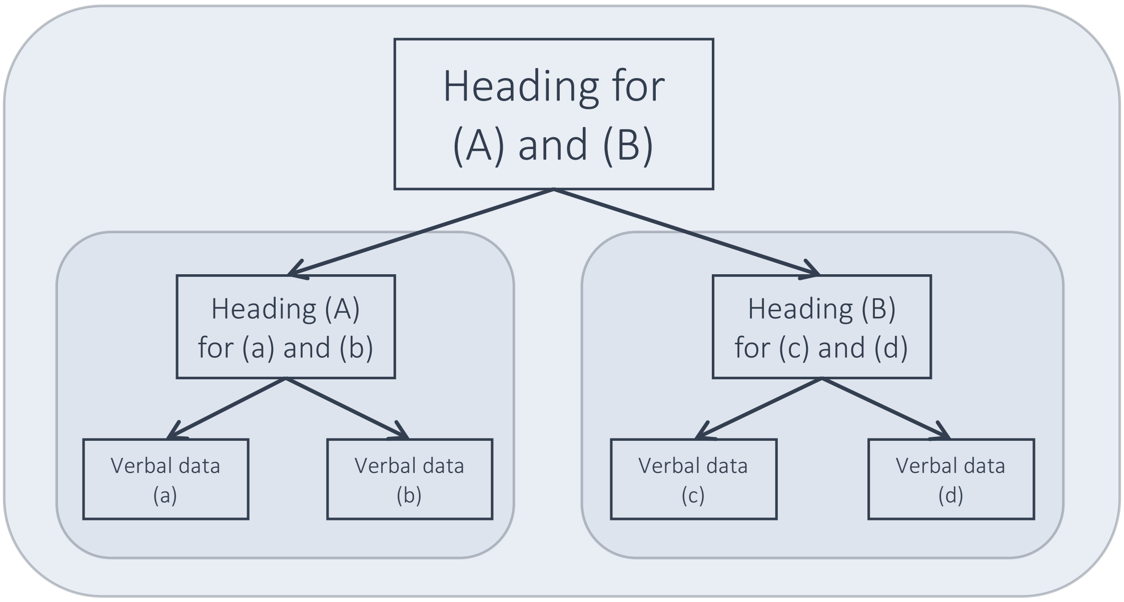


Figure 7. Conceptual illustration of how the data has been analyzed in the thesis in terms of the developed groups

The aim of the data analysis has been to structure the data and to develop a result for this thesis. The foundation of the result has been based on the interviews with the operators, which then has been supported and strengthened by the interviews with other relevant roles in the operations of Volvo Group as well as adding new insights, especially about improvement potential in a long-term perspective. Also, a comparison at another business unit has been conducted at Volvo Penta to gain even more knowledge about assembly information and how it has been used and this is presented in Appendix A. A conceptual model of the results is shown in Figure 8.

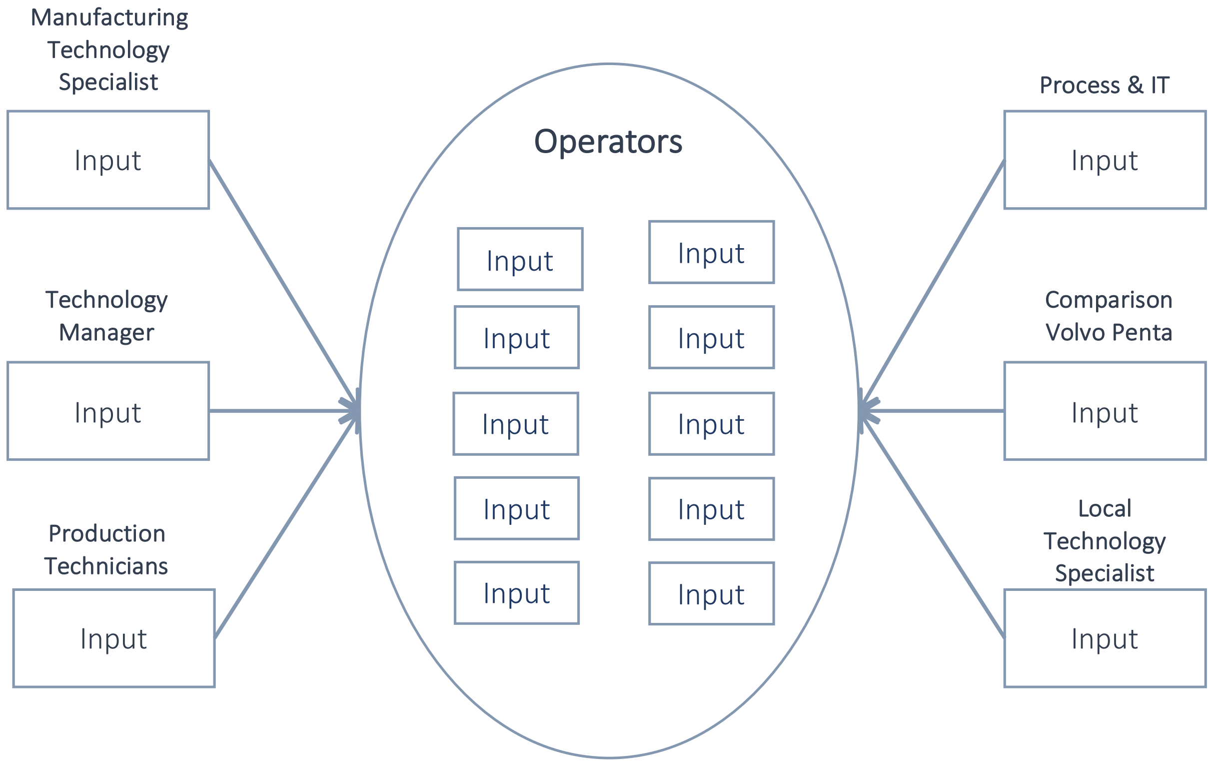


Figure 8. Conceptual illustration of the results in this thesis.

3.6 Research Quality

According to Bryman & Bell (2015), two main aspects for evaluating the quality of qualitative research are trustworthiness and authenticity. Trustworthiness are based on four criteria which are: Credibility, Transferability, Dependability and Confirmability.

3.6.1 Credibility

The aspect of credibility considers if the results are acceptable to others and how believable the results are (Bryman & Bell, 2015). In order to ensure the credibility, triangulation has been used to strengthen the findings. Triangulation refers to using more than one method or source of data and therefore have data from literature studies, interviews and a comparison been used in this thesis.

3.6.2 Transferability

Transferability consider how well the findings can be applied in other contexts (Bryman & Bell, 2015). The results of this thesis are consequently written in a general approach, where the analysis and result can be applied in other types of companies with similar environments. Also, the data gathering has been extended to include comparison of another organization to ensure the relevance in additional contexts.

3.6.3 Dependability

The criteria of dependability have been emphasized by applying an auditing approach, meaning that records of all phases of the research process have been stored. Also, the research process, problem formulation and research methodology have been clearly stated in this thesis. Further, questions of the interviews have been provided as well as a description of how the analysis of the data has been conducted.

3.6.4 Confirmability

Bryman & Bell (2015) describes that confirmability considers the fact that it is important for the researchers to be objective throughout the whole research process. They state that this is challenging in qualitative research, however, it is therefore important to emphasize that personal values or previous knowledge not will affect the research in any direction. This has been ensured by e.g. having both internal supervisors and external supervisors from outside the case company.

3.6.5 Authenticity

Bryman & Bell (2015) further argues that it is important to include the criteria of authenticity when evaluating the quality of the research to raise the discussion about the political impact of the research. Authenticity consists of the following five factors: fairness, ontological authenticity, educative authenticity, catalytic authenticity and tactical authenticity.

Fairness consider if the research can represent the members of the observed social setting. This thesis has focused on the operators in the production system and consequently been the largest part in the data collection. The thesis has included an extensive number of operators that have been divided into 13 use cases in order to represent common truck assembly operations throughout the organization. Also, interviews with participants in different levels such as production technicians, MTS, LTS, technology manager and director Process & IT have been included to be able to get results that are representing more levels in the system and therefore ensuring the fairness. The factor regarding ontological authenticity emphasizes that the research should help the members to get a better understanding of the phenomena that are being researched. It has been secured by given multiple presentations in the different stages of the research as well as shared the data and the analysis with the influenced members. These actions have also led to that educative authenticity has been included in the thesis, since the presentations and results have been shared with the different participants, giving them a better understanding of the different members and their situations. The catalytic authenticity has been emphasized since the results of this thesis have opened for discussion of how Volvo GTO could improve in the future, which has engaged the members to use the results of this thesis in further analysis. Lastly, since the focus of this thesis has been on research, focus areas for the future and radical innovation rather than continuous improvement, incremental change and quick implementation, the factor of tactical authenticity has not been the most prioritized in this stage. However, the results are going to be used in further analysis at Volvo GTO, which in the long term will open possibilities to improve and take actions and consequently address the tactical authenticity.

3.7 Ethical considerations

When conducting research, it is essential to continuously emphasize the ethical aspects. Bryman & Bell (2015) state four main areas to consider when conducting research, which are:

- Harm to participants
- Lack of informed consent
- Invasion of privacy
- Deception

These areas have therefore been permeated the process throughout the whole thesis, especially in terms of how the data have been gathered and analyzed. In order to ensure that no ethical considerations have been violated during the study, the following actions have been taken. All participating interviewees have prior to the interview been informed about the purpose of the thesis and how the data would be analyzed and presented. Also, all interviewees have been anonymous throughout the whole thesis and recordings have only been collected if it has been accepted by the interviewee and then only used by the researchers. The data has been used and analyzed to develop general results, meaning that it would not be possible to distinguish statements or opinions from particular participants. During the interviews, the participants have always had the right to not answer particular questions and to withdraw their participation.

4. Results

In this chapter, the collected data has been analyzed according to the predetermined methodology and thus presented in the groups developed during the analysis part of the thesis. The groups from the first as well as the second grouping can be seen in Appendix G. The current state has been established, problem areas has been identified as well as the improvement potential in terms of focus areas. These areas have then led to the answer of the sub research questions respectively and consequently answering the main question of assessing the information needs, potentially leading to an improvement of the quality in manual assembly. The first part of this chapter is an introduction presented directly below with the general findings such as the use of instructions, quality problems and the perceived work difficulty in order to frame the topic as well as create a sense of urgency for further findings and consequently followed by the two main sections, Process problem areas and Focus areas. Further, the results from the data gathered and analyzed from the other relevant roles in operations as well as the comparison with Volvo Penta can be found in Appendix B and Appendix A respectively and are used to support, strengthen and increase the comprehensive understanding.

In the first main part, the identified problem areas are considered and these factors need to be emphasized to ensure proper working methods in these processes, which would lead to a direct impact on the production quality. But more importantly, it will stabilize the processes, ensure support towards operators on a long-term basis, increase the satisfaction and to enable and sustain further improvements. The second main part consider the developed focus areas that are directly connected to improvements of the assembly information and describes the direction needed to be considered in order to ensure sustainable assembly information in the future. Altogether, the results and its particular findings are conceptually illustrated in a model in Figure 9, where it together visualizes the information needs in manual assembly.

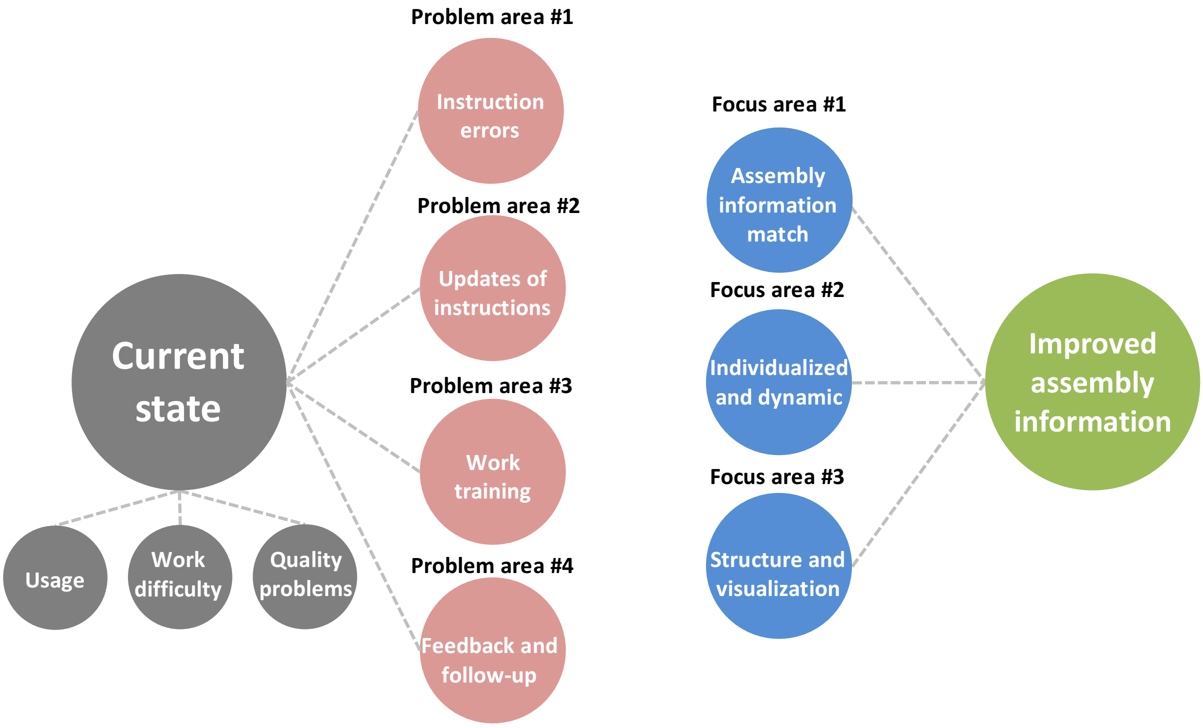


Figure 9. Illustration and presentation of the results based on current state, problem areas and focus areas.

The general findings consider the usage of the instructions, the main quality problems and the work difficulty and are based on the data gathered during the interviews at the case factories. According to the data, there are a substantial variation in terms of usage of instructions, both between factories as well as between stations and operators. For example, 32% of the operators are never or rarely using the instructions and 60% state that they use the instructions on every truck (because they must use instruction or Pick-to-Light to work, however, majority is not satisfied anyway) and the rest is in between. Approximately, one in three operators (32%) want to use the instruction only when they do not know what to do, since they mean that they know the rest. However, the vast majority (88%) state that they primarily using their own experience instead of instructions in general. In Plant A, the usage is generally lower than in Plant B and Plant C. The majority of the operators are stating that it is impossible to have enough time to read the instructions thoroughly and they are only searching for the specific information they need by looking a couple of seconds, also there with the largest emphasize on Plant A, which is due to the form of the instruction where Plant A is based on an extensive paper instruction (example in Appendix C) and Plant B/Plant C have the digital MONT system for digital instructions (example in Appendix D) with reduced information. There is also an increase in handling time of the instructions, sorting and changing instructions, when they are on paper than it would be if they have been computerized, which also leads to the in general lower usage of instructions in Plant A.

According to the interviewees at all three case factories, the work difficulty of their work most of the time are low. However, sometimes in Plant A does the work difficulty depend on which type of truck that they are building, e.g. special trucks or variants that are not so common. Although, generally it has been found that the time and stress aspect are more evident than the difficulty level. Even though the work is perceived as easy, they are still having quality problems across the case factories. According to the operators, the most occurring general quality problems are related to assembly errors in terms of missed/forget parts, wrong part, assemble on the wrong position, careless mistakes, technical issues with the pick-to-light system and lack of time so the time for adjustment and controlling are sacrificed. Many of these where, according to the operators, related to that the instructions are not satisfactory due to issues that will be brought up in the following sections. Also, it has been brought up during the interviews that the production is extremely sensitive to employee turnover and capacity variation (assign extra personnel) due to the unsatisfactory instructions since both the severity and frequency of quality problems have been increased during these periods. Hence, the needed knowledge is often tacit and built up with experience and not properly presented in the instructions. It has been primarily stated by operators in Plant A (75%) but also in Plant B (29%) and Plant C (33%), where they argue that the instructions are e.g. hard to understand for new operators. Consequently, longer learning curves and more quality problems are created, especially initially. In addition, according to the data, there is a problem in Plant A with having the instructions on paper since they must be matched with the right truck, also it increases the handling time and risk of errors.

4.1 Process problem areas

In this section, the findings that are connected to the process problem areas of the current state in terms of working methods are presented. These are factors that are crucial in order to sustain and support successful processes and working methods in connection with the assembly information and the instructions, however, not functions sufficiently today. These improvements need to be implemented before the focus areas in order to stabilize the processes, increase the satisfaction among operators and to enable further improvements. Therefore, these need to be emphasized to improve the assembly information system. In Table 5, a summary over the groups included in this group can be found.

Table 5. Summary over the groups included in this chapter.

Group	Main takeaways from each group
Instruction errors	• Instruction errors occurs, leading to uncertainty and quality problems • Creates a "Do not care about the instructions" attitude, thus decreasing trust • Although, better the last couple of years • The operators feel involved in the development and updating of instructions
Updates of the instructions	• System constraints on SPRINT, creates long lead time on changes • Long lead time on changes in the instructions lead to a lot of temporary instructions and thus uncertainty and quality problems • Time between instruction updates are too long, leads to outdated instructions

Work training	• Only trained at the line
	• Variation in how the work training is conducted
	    o Creates different levels of knowledge
	    o The use of instructions is not sufficiently emphasized in education
	    o Instructions not good enough to compensate
	• Low comprehensive knowledge e.g. regarding more than one particular station, leading to quality problems further down the line
	• Above factors lead to that the work is not standardized, everybody performs it differently

Feedback and follow-up	• Bad feedback on assembly errors • Poor follow-up on implementation of new instructions leads to that they are not adopted

4.1.1 Instruction errors

Another significant issue that has been brought up in the interviews are the errors in the instructions. 44% of the operators state that there occurs errors in the assembly instructions and this fact are spread throughout the case factories, even more frequent when encountering special-trucks. However, most of the operators stated that the instructions have been improved during the last couple of years, which have reduced the number of errors significantly. 56% of the operators state that they trust the instructions most of the times. But, when errors occur a mentality of "do not care about the instructions" are being increased and the trust are being decreased, therefore is it an important factor. Also, it has been stated that the number of errors always are higher when rebalancing. Hence, the importance of having a flexible and quick process and system to make rapid changes. However, 88% of the operators across the case factories feels that they have an opportunity to be included in the development and updating of instructions by leaving feedback to production engineers or group leaders, who then takes it further and if possible, fix the problems.

4.1.2 Updates of the instructions

At Plant A, which is using SPRINT, there is a three-week window from when an error in the instructions are identified and corrected until it is possible to see the change in the instructions. This window is created due to constraints of the SPRINT system and according to at least 40% of the operators inviting the opportunity of performing errors in the assembly process during this time due to uncertainty. It is mentioned at all three case companies that it in general takes too long before errors are corrected in the instructions, which leads to a lot of temporary instructions that could be e.g. hard to keep track of, remember to use and to know when to use. Also, the frequency of general updates of instructions is low according to 35% at Plant A, 30% at Plant B and 17% at Plant C, which leads to outdated instructions in terms of working method, components and variants. This is often due to that the technicians do not have the ability to make changes in the instructions, its layouts or its contents and therefore need to send if further and this process can be extremely time-consuming. It has also further been emphasized in the findings from the interviews with the additional roles, presented in Appendix B. As described before, this also argues for the importance of having a flexible system in order to ensure employee satisfaction as well as decreasing uncertainty and quality problems.

4.1.3 Work training

According to the data from the interviews, the education, work training and knowledge are a important factors. All the interviewed operators answered they conducted their initial training at the production line by following other operators. Some of them mention an introduction day with general tour of the plants and in some cases, try out some of the tools, however, there are no proper or off-line training towards the role as an operator, which is argued as unsatisfactory for the vast majority of the operators. Since other operators are educating new operators, it exists a substantial variation in how this training is conducted, which has been brought up by 48% of the operators, especially at Plant A. Also, 56% of the operators said that the workers obtain different knowledge due to this variation. There are even examples of when the “educator” did not even explained that the instructions should be used when working as well as cases where a new operator has been trained by an operator that only had 2-3 weeks of experience. Further, few of the asked operators said that their “educator” explained how to read and use the instructions. This leads to that the new operators are put at line with an unsatisfactory education and too low level of knowledge, thus making it harder and more time-consuming to gain the proper level of knowledge and simultaneously risking quality. Thus, even more important to have proper instructions to support the operators, which is not established today, especially at Plant A.

Further, another important aspect is the fact that 56% of the operators stated that operators generally lack a comprehensive understanding about the work, which also is causing quality issues. In general, there is a lack of the why - knowledge in production, and this has been identified across the case factories. This knowledge is neither educated initially nor given by the instructions properly. An example of this knowledge is the understanding of what is happening before and after that particular operator’s station and work task and if it is not secured, it leads to low levels of knowledge about the product and the processes. An operator can perform a certain task in a way that will cause problems or extra work further down the production line without knowing, and therefore cause quality problems.

All of the above mentioned issues lead to that the manufacturing of the products are not performed in a standardized way of working and the operators are working in their own and variating way, which is stated by 56% of the operators. It is therefore essential that firstly, there is a sufficient training initially and continuously for the operators and secondly, have an information system (assembly instruction) that facilitate standardized work, especially emphasized for new operators.

4.1.4 Feedback and follow-up

When an assembly error is detected, the operator responsible should be notified and given feedback about what has been wrong and how it can be avoided, but according to 58% of the operators in Plant B does this feedback not exist or is very sporadic. This absence of feedback and follow-up also leads to the fact that 28% of the operators does not use the instructions and that new instructions are hardly adapted and hence leading to missed information and quality problems.

4.2 Focus areas for improvements

In this section, the results based on the focus areas for improvements will be presented in the groups developed from the analysis of the data. The groups are Assembly information match, Individualized and dynamic information and Structure and visualization and are respectively describing important aspects to emphasize in order to improve the assembly instructions, its system and how it is perceived by the users. In Table 6, a summary over the groups included in this group can be found.

Table 6. Summary over the groups included in this chapter.

Group	Main takeaways from each group

Assembly information match	• Low match between presented and wanted information, leading to quality problems
	• Additional information needs:
	  ○ The right amount of information, when it is needed
	  ○ Information about how a task should be performed
	  ○ Information of a part's position
	  ○ Changes
	  ○ Sequence
	  ○ General knowledge to build understanding etc.
	• Support by pictures
	• Feedback during work, e.g. pick to light
	  ○ Used for quality control

Individualized and dynamic information	• Difference in information needs between operators • *"The instructions are to extensive for expert operators and too poor for novices."* • Need to increase the usage across the employees • Individualized and dynamic information dependent on operator experience level, product frequency, urgent quality problems, changes since last time etc. • New employees need more information based on step-by-step • Experienced operators need information about changes, non-frequent products and quality problems • Secures the perceived value and usage

Structure and visualization	• Hard to use current SPRINT instructions, need to search for information
	  o Too much text and numbers
	  o Information is divided and it does not always follow work sequence
	  o Too technical language, hard to understand
	  o Repetitive information gets the same emphasis as more important information
	  o Hard for new operators to understand and learn
	• MONT is more clear and easier to follow.
	• Lack of proper structure and visualization leading to quality problems, longer learning curves and insufficient support.

4.2.1 Assembly information match

From the data, the information the operator needs and searches for today in the instructions as well as the additional information needs for the future have been identified. Although there are differences between the factories depending on the environment and product, there are some general information needs that are the same. Generally, it can be stated that the assembly information match is worse at Plant A than at Plant B/Plant C, since the operators are more satisfied in Plant B/Plant C. However, the products are more complex in Plant A, the cycle times are longer and the product range and thus also the variation is bigger. But the fact that Plant A are having paper instructions and Plant B/Plant C have digital instructions are also considered. The information that is used in the instructions today as well as additional needs are summarized in Figure 10 and more in detail in Appendix G.

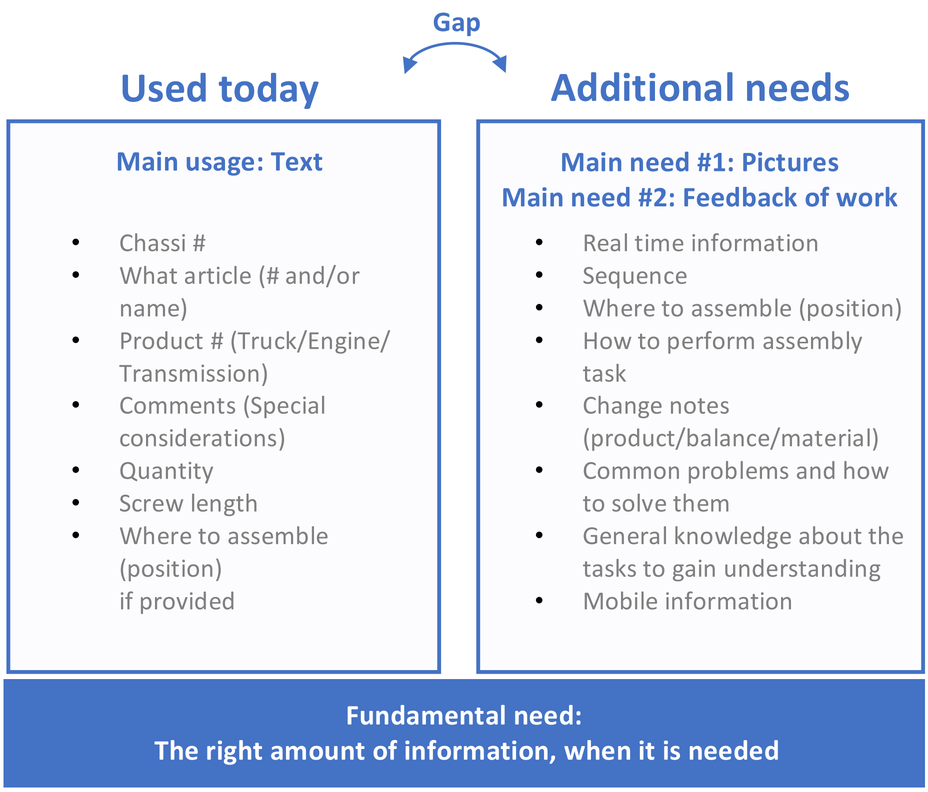


Figure 10. Summary over the information used and the additional needs not provided.

Generally, the match between the presented information and actual needs is low, especially at Plant A. There is too much information presented, which are not used (further discussed in 4.1.4) However, there are still a greater need of better and more tailored information. Firstly, the fundamental need, which is found across the case factories, is that the operators need the right amount of information, when it is needed, in contrary to in the current state where there are both too much and mismatched information. Also, in Plant A this information is presented at the same time (SPRINT/paper instruction) and hence not when the information is needed, leading to an overwhelming amount of information and longer search times. It is perceived as better in Plant B and Plant C, since the information is digital and presented in the right sequence and order of the tasks.

Generally, the usage today is mainly text based, either on paper (SPRINT) or digital (MONT). Although, there are picture support on some of the tasks in especially Plant B and Plant C (MONT system). During the interviews, it has been stated that the first main information need across the case factories is picture support, in order to faster receive the information, but also to get more support in terms of position and how to perform the task. The interviews provided clear evidence of a need of more pictures in Plant A, 75% of the operators want pictures of e.g. different hole patterns and on special trucks to ease the understanding about the work and to make the learning go more smoothly. At Plant A, there is also a wish of installing screens with both instructions and pictures, that the operators can interact with to better support them. All the case factories agree upon the fact that pictures are good for learning and it can also work as a quality control, since the operators can see how it should look like when that operation is performed and the components attached to the product. They also agree upon that there cannot be pictures of everything because that would make the instructions too long, and therefore should pictures of special variants, critical work and low-frequency products be prioritized. As given by the interviews at Plant B and Plant C, it has been mentioned that the pictures are too zoomed and that the colors flow together making it hard to interpret the picture and therefore is the quality of the pictures important for the quality of the work.

Further, the second main need is feedback of work, meaning that there are tools or systems that controls and sends feedback to the operator during or directly after a task through e.g. pick-to-light or connected tools. All stations that have pick-to-light or tools connected to a system is experienced to give good and sufficient feedback to the operators at all three case companies. However, it is still important to not make it too rigid, which also has been argued by the operators. Plant A only has pick-to-light while Plant B and Plant C also have connected tools to MONT. In Plant B, only some stations have been equipped in contrary to Plant C where all stations have been equipped with tools or hand scanners. Even if all the operators in Plant C thinks the feedback is good, 50% of them also thinks that the work today can be perceived as controlled with the pick-to-lights, scanning of articles and tools connected to the MONT system, thus important to emphasize the quality control versus rigidness trade-off to find a proper balance. Almost all operators in Plant A and Plant B mentioned that they want to have feedback when assembling important parts, which will create a form of continuous quality control that allows them to see directly if a part is correct assembled or not, which then radically would contribute to improved support and hence improved quality. The MONT system used in Plant B and Plant C is according to 83% of the operators at Plant C a good system when it comes to giving feedback. Since it is impossible to send the transmission further down the line until all operations have been done, and because all tools are connected to the system, a quality control automatically are being performed on all operations. Even though MONT is considered to be sufficient there is still several operators that avoids using it unless they do not know what to do, this attitude exists in 67% of the operators in Plant C and 28% in Plant B.

On the left-hand side of Figure 10, the information used today are presented and on the right-hand side the additional information needs, not provided today, are presented. Hence, a gap between the information used today and the additional need that are not sufficiently provided are being identified and visualized in the figure as the difference (or mismatch of information need). The additional need that is identified and assessed consists of several factors. The operator needs the information in real time, meaning that the information should be presented when needed and removed when used. This is not provided in Plant A but provided in both Plant B and Plant C leading to that operators in Plant A develop an uncertainty about if tasks have been done or not, especially since the cycle time is long. This is also connected with that the sequence of the task should be provided to make it easier. Further, there is a large need for more support in terms of where to assemble (75% in Plant A, 30% in Plant B/Plant C) as well as how to perform a certain task (100% in Plant A, 23% in Plant B/Plant C), especially for variants with low frequency. It has been identified as a major factor for some of the most frequent quality problems. Another important factor is the need for information about changes e.g. in product, balance, material or assembly, which is not provided in a sufficient extent today. The operator need to be alerted through the system that changes have been performed and not just change the instructions and assume that everybody will see and understand it. It has also been stated in the interviews that additional information regarding common problems or critical tasks and how to solve need to be addressed in a larger extent, where it today leads to waste and time-consumption. Moreover, 76% of the operators across all case factories argues for that the general knowledge and understanding are too low due to it is not sufficiently taught nor sufficiently provided in the instructions leading to quality problems. For example, if there would exist a greater understanding, operator at preceding station would know why and how they should perform their tasks in the best way, not creating problem further down the line, which is experienced today. Finally, it has been identified that the mobility is of importance for the operators to reduce walking and waste, especially in Plant A where the products and hence the stations are large. The most of the above mentioned factors are eventually learned by experience, however, when it is not provided it makes the production more sensitive to employee turnover, capacity variation, it is prolonging the learning times for operators, increasing quality problems and most substantially, leading to non-standardized work and greater variation.

4.2.2 Individualized and dynamic information

In the interviews, it has been stated from the majority of the operators that the information need varies depending on the experience level (e.g. novice/beginner/experienced/expert), hence leading to the variation of instruction usage. For example, it has been stated that *"the instructions are to extensive for experienced operators and too poor for novices."* and therefore are on a satisfactory level only for a short period of time for the operators. This has therefore led to that the operators prefer using their own experience rather than the instruction (88%), since the usage value is too low for their actual experience level. Further, several operators stated that they want to choose the level of information based on their own preferences and therefore have individualized information. Suggestions regarding the feature of logging in into a system where it is possible to personalize the information in terms of views, level of information, change notes since last time and images have also been emphasized in the interviews. An example of the level of information has been given by several of the more experienced operators who argued that the amount of information on each instruction is "the same on every product" and they want the ability to instead highlight or emphasize information on the variating components or activities instead of the kind of information they know by heart. This would consequently lead to less unnecessary time spent on searching for the relevant information and fewer quality issues in terms of "missed/wrong part", which has been stated as one of the most occurring issue. This subject has also been emphasized by several of the other roles as well as the comparison and can be seen in Appendix B and Appendix A. A more detailed explanation of the concept of individualized and dynamic instructions based on the findings can be seen in Figure 11, where it can be compared to a ladder with several levels.

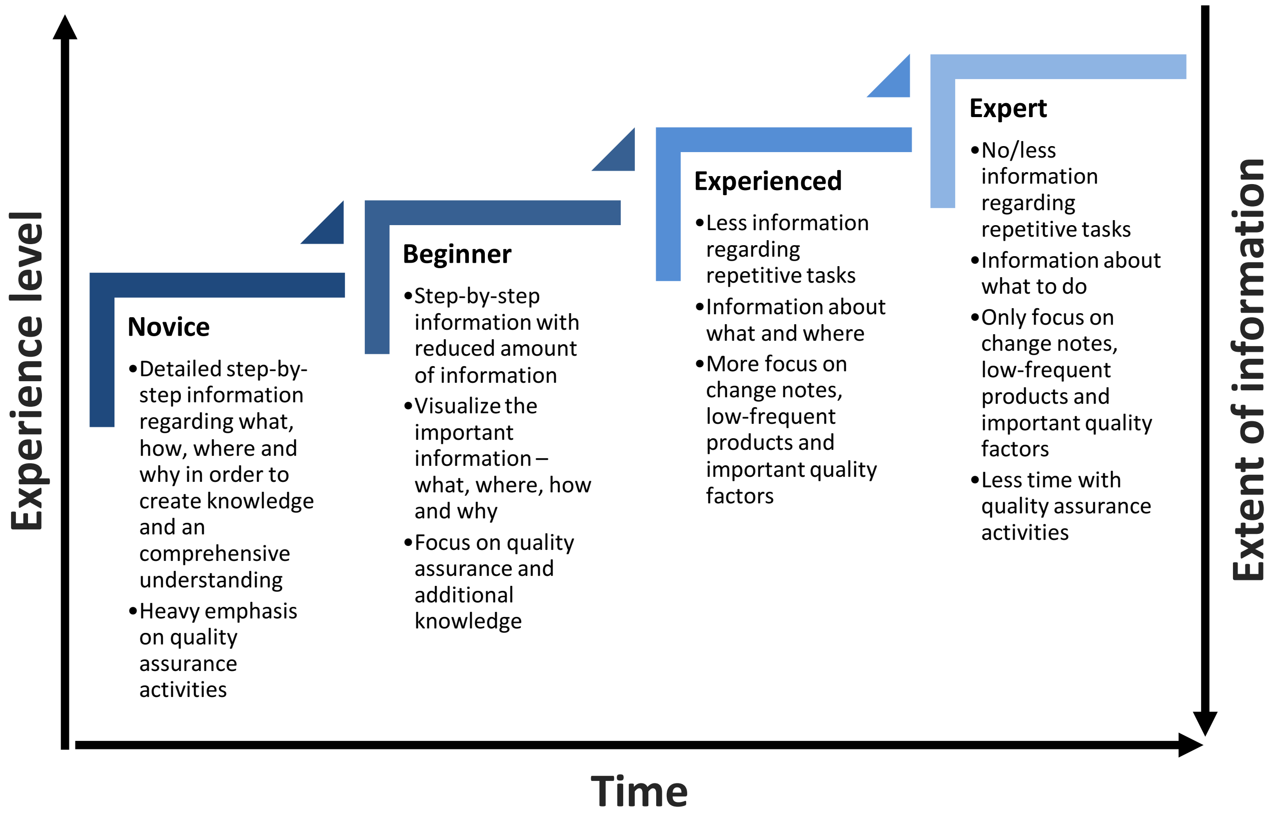


Figure 11. Explanation of the concept of individualized and dynamic information.

In order to ensure the right amount of value for each operator based on experience level, the instructions should be individualized and dynamic, where the amount and characteristics of information should be decreased and changed as the experience level and time increases. The information focus on each level is shown beneath the respective level. Initially, the focus for the novice is to create an understanding and building knowledge about the work. During this time, in addition to the common factors of what to do, a bigger emphasis on where, how and why should be addressed to foster this understanding. The instructions should also be based on a step-by-step basis so that the correct and standardized assembly process is thought, followed and then learned. Also, the system should dynamically and more frequently conduct quality assurance activities and request validation from the operators to ensure the quality in this stage. As the experience level increases, the information level can be allowed to decrease over time. The information should be reduced stepwise in the ladder, where the most important information should be highlighted. In the upper levels of the ladder, the information should primarily consider what to do, change notes and urgent quality messages, while the rest could be reduced to ensure the usage value, even for experienced operators.

4.2.3 Structure and visualization

From the interviews, one of the biggest issues with the instructions have been the structure, logic and visualization of the instruction. However, this has almost solely been the case in Plant A and in terms of the SPRINT instructions (example in Appendix C), where the operator in Plant B and Plant C are satisfied to a higher degree with the digital MONT instructions (example in Appendix D).

The most significant issue with the SPRINT instructions is the fact that they hold an extensive amount of information, text, numbers and codes. However, a lot of information is rarely or never used by the operator which consequently leads to that it is difficult to understand, search for and digest, which is stated by 83% of the operators in Plant A and 54% in Plant B and Plant C who only search for specific information. Equal and subsequent activities can be divided and totally separated on the instructions, leading to assembly errors due to missed parts. Also, the information that is “the same for each product” gets the same emphasis as the more important information regarding variating components and critical work. This information should therefore be highlighted or signaled to the operators to ensure that this information is seen and used. Further, 42% of the operators in Plant A state that the language is too technical and difficult to understand, leading to unnecessary uncertainty. All of the above mentioned issues lead to that the instructions are hard to understand and use properly, thus also prolonging the learning curve as well as increasing the extent of quality problems for new operators, which is stated by 75% of the operator in Plant A and 52% of the operators in total. These issues have also been raised in interviews at Plant B and Plant C, however, not in the same extent as in Plant A, since it is the only plant using the paper-based SPRINT instructions. The instructions at Plant A can rather be compared to a bill-of-material than a proper instruction and they should instead be more user-friendly and developed to fit the characteristics of assembly tasks instead of as a material list for other activities, as it is used for today. Consequently, there is a lack of proper visualization and sorting of relevant information and the above mentioned issues lead to that operator's miss parts or activities, take wrong part or assemble the parts on wrong positions, due to the lack of sufficient support. Also, the lack of digitalization (paper instructions at Plant A) are making these issues even more substantial.

5. Discussion

The goal of this thesis is to assess the information needs to be able to improve the assembly information and hence the quality in manual assembly and has been conducted through answering the research questions. The thesis has therefore aimed at identifying current problem areas and developing focus areas for improvements, which then are answered and discussed below together with relevant theory, the findings from the additional interviews and comparison with Volvo Penta, in order to draw conclusions.

Firstly, the general findings have been discussed and thus presented directly below. The first main part of the discussion emphasizes on the identified problem areas and how they need to be emphasized to be able to implement the results and a future assembly information system which then address the first sub research question. The second main part of the discussion are emphasizing on the three developed focus areas together with relevant theory for a future assembly information system and hence address the second sub research question and are discussed respectively. Also, when this new system is being developed, the results in this thesis can be the basis for creating requirements, which is crucial when developing new systems (Hull, Jackson & Dick, 2011) and hence included in the discussion of both problem areas and focus areas. The discussed requirements have been expressed in the functional requirement domain, which according to Hull, Jackson & Dick (2011) means describing what the system should be able to perform. For the non-functional requirement domain (how the system functions), further emphasis should be performed with the aim of study how a new system could be developed and operate. Altogether, this discussion considering problem areas and focus areas in connection with theory, standardization and requirements contribute to the answer of the main research question regarding the assessed information needs to be addressed in order to improve the assembly information and hence the quality in manual assembly. Lastly, the opportunities for standardization and its implication for Volvo, the research quality as well as future research has been discussed.

Volvo has for several years been focusing on acquisitions leading to diversity in processes, products and systems. Consequently, there is a lack of standardized way of e.g. producing assembly instructions leading to a difference across countries and factories in how the instructions are used and utilized, which is supported by Johansson (2016). This variety can, as stressed before, drive cost, quality and productivity negatively and need to be handled in a proper manner (Fisher & Ittner 1999; Johansson, 2016). This factor is also emphasized from the interviews with for example the LTS, where it has been argued for the difficulty to create sufficient instructions with the extensive number of available variants. Liker & Meier (2006) means that in order to continuously improve and be competitive, there need to be a foundation of standardization and therefore, the purpose of this thesis has been to assess and identify what needs to be emphasized to be able to standardize how future assembly information should function and be utilized in the future. It has then the potential to lead to an improvement of the assembly information and hence an improvement of the quality in manual assembly. In this thesis, the usage of instructions has been identified as varying and thus leading to quality problems and assembly errors such as missed parts, wrong parts, carelessness and lack of time leading to less emphasis on adjustments and quality controls. The fact that assembly errors are the most experienced issue in this kind of environment has also been addressed by Johansson et al. (2016). For example, 32% of the operator stated that they never or rarely use the instructions and due to the extensive product range, it is inevitable to experience these kind of quality problems. Consequently, the perceived value of using the instructions are too low for operators. Enofe (2017) and Schwarzkopf (2017) are also stressing this factor in their study, where they have identified gaps between the availability, usage and importance of information in the assembly instructions. Generally, the situation at Plant A (SPRINT/paper instructions) has been assessed to be perceived as worse than in Plant B and Plant C, where they utilize the digital instruction system MONT. Based on the above reasoning, the information needs in terms of problem areas of the working methods and focus areas for improvements are being discussed below. Also, this is connected with relevant theory and possible requirement areas for a future assembly information system. Followed by a discussion about the possibilities for standardization and its implications and lastly, future work as well as the quality of the thesis are being discussed.

5.1 Current problem areas and how to implement the changes

Moreover, in this thesis a number of problem areas have been identified. These can be considered as areas that need to be emphasized and solved before a new developed assembly information and its system can be implemented. Firstly, due to that the suggested focus areas are improvements that take long time to develop and implement, the performance need to be improved as good as possible immediately, which can be achieved by solving the problem areas. More importantly, the processes will be more stable and ready for further improvements as well as the satisfaction, acceptance and support among the employees will be substantially improved and hence lead to less resistance when implementing a new information system, which would be beneficial for the implementation project as such since resistance can lead to loss in time and productivity or even terminate the whole project (Palmer, 2004; Kotter & Schlesinger, 2008). The above reasoning is visualized in Figure 12, the result model is shown together with a timeline, representing the order of introducing changes. The current state is how Volvo GTO is performing today and the problem areas need to be emphasized and solved before introducing the focus areas. This would lead to improved assembly information and hence improved quality in manual assembly.

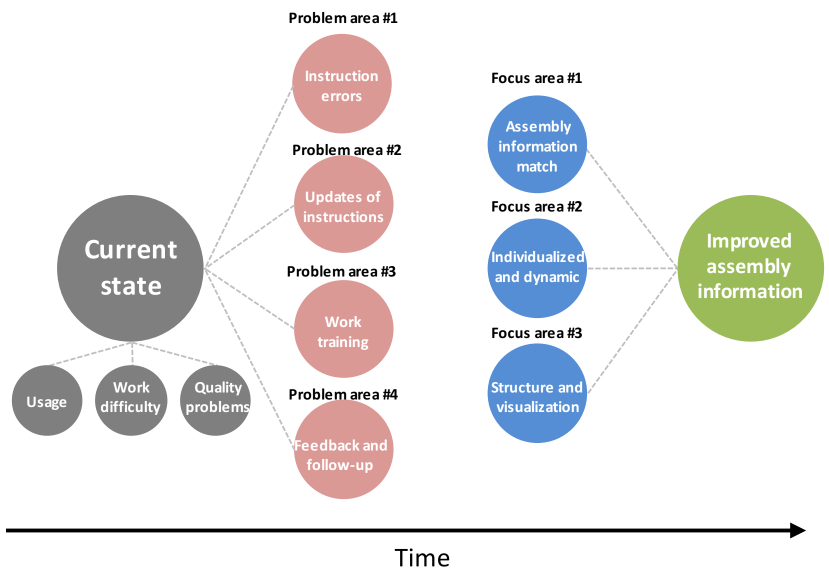


Figure 12. Visualization of the order of introducing changes

Secondly, there is a possibility to reduce some of the quality problems if the work training is conducted in a standardized and good manner that lead to better understanding and knowledge about the work, correct instructions, better feedback when problem occurs and follow up on standardized work as well as quicker updates of instructions. Since these are factors of working methods and not directly of information, there are not as many requirements for a new assembly information system. However, the system should still facilitate proper work training and step-by-step instructions in order to enhance learning, quality and standardized work (Lander & Liker, 2007). Also, a standardized way of teaching new operators should be developed to ensure a sufficient amount of knowledge, where the instructions and assembly process can be thought off-line, before starting working at the production line. This factor of work training has also been emphasized by several of the other roles, meaning that more focus should be applied on initial training before starting at line to ensure quality as well as employee satisfaction. Further, the system should also be easy and flexible to update and make changes in (addresses both the problem area of Instruction error and Updates of instructions) since it mainly depends on system constraints today, which has been emphasized by e.g. operators, MTS, Director Process & IT and Technology Manager as a substantial problem. Therefore, a future information system need to be developed to be flexible and therefore handle quick changes. Further, it is even more crucial in a more fast-moving and demanding business environment to gain and maintain a competitive advantage in the future (Hu, 2013; Oliinyk et al., 2015). Also, emphasized by the MTS meaning that the future demands more quick changes in e.g. rebalancing or other changes in the production line in order to utilize the capacity and employees in the best possible way. In addition, Marksberry, Vu & Hordusky (2011) argues that it is important to be responsive to gain commitment and loyalty among employees, which is perceived as a risk today due to instruction errors and thus creating an environment of decreased trust. Further, the system should facilitate feedback towards operators in terms of performance and quality (e.g. assembly errors) by collecting data and presenting it in a visualized and understandable way for further analysis, feedback and follow-up. Consequently, the above mentioned factors should also be key functional requirements in a future information system.

Thirdly, if these problem areas are not solved when implementing a new information system, there is a possibility that the results will not be optimal and more importantly, it will not be successful over time due to degradation caused by bad training, instruction errors, slow updates of instructions and insufficient feedback and follow-up. Consequently, the problem areas can be seen as enablers of the new information system and the focus areas could be seen as drivers of the new information system, where both are equally important to be able to improve the assembly information and hence the quality in manual assembly.

5.2 Assembly information match

One of the biggest concerns with assembly instructions today is that they are not developed in consent with the ones that are going to use them, which often lead to missing information and thus leading to the first focus area. Although the operators experience missing information, they also experience excess information. Therefore, it is important to include the user when deciding both which type of information (e.g. pictures, text, etc.) and what information that is going to be included in the assembly instructions, in order to get instructions that is easy to use and also contains the necessary information to perform each task.

The results argue for, and also mentioned by Enofe (2017) and Schwarzkopf (2017), that there is an excessive amount of information in Plant A where several parameters, such as: *Sequence Number, Serial Number, Assembly Line, CI (Core Instruction), C1, C2, Emballage (Emb), Use Point (UP) and Time Study,* which are not used by the operators while some of them are used by the production technicians. In Figure 10, the information that is commonly used by the operators have been compiled, which consequently strengthen the claim by Enofe (2017) and Schwarzkopf (2017) and therefore are several parameters unnecessary to include in an instruction. Today there exist assembly instructions that are several pages long and therefore, makes it hard for the operators to find what they are looking for and for new operators to know what information that is important. Even though the instructions are too long there is still a lack of information, where they describe their main needs as pictures and feedback of work. They want pictures in order to create a better understanding of their work but also to see where the parts should be assembled and pictures can also give feedback, since it is possible to compare the picture with the reality. As mentioned by Osvalder & Ulfvengren (2009) it is advantageously to present information in more than one way, e.g. pictures and text, because that would make it easier to understand. In addition, Li et al. (2013) further mentions that it is best to use realistic pictures to communicate the right information. Key requirements for future information system and its instruction should therefore be to include pictures of complex tasks, more information about “how” to assemble and “where” since this is wanted by the operators and can lead to more general knowledge as well as increase the mobility of the information to reduce waste (Liker & Meier, 2006). The mobility has also been heavily emphasized by the Director of Process & IT as an important factor to consider in future applications.

The operators are today involved in the fail search and improvement of instructions, but in the future the operators should be involved in the creation of instructions as well to secure the consistency and that the information match the needs. But also, to keep the instructions short and manageable. These requirements are strengthened by the fact that another system that has been developed that lets the operators take responsibility for what information that is in the instructions, which has been the case in the comparison with Volvo Penta. One operator is responsible to make sure that the right information is in the instructions in terms of text and pictures. Otherwise, they have the authority to fix it, and this system has together with other factors reduced the assembly errors with 50%. This also lead to another requirement, which is to give the operator's responsibility so they feel committed to their work. The above reasoning has also been supported by e.g. the MTS, LTS and the production technicians, where they argue that it is important to continuously address the match between the information and the true need, however, the system today is too inflexible to fully conduct this type of action due to constraints.

Previous research by Enofe (2017) and Schwarzkopf (2017) shows that the importance of various information, such as e.g.: *Part Name and Part Number,* differ between the operators and the engineers. It strengthens the claim made by the operators during the interviews that the instructions are not completely designed for them as well as that the language in the instructions is too technical, which makes it hard for the operators to fully understand what they are supposed to do or how to do it. This is something that the engineers acknowledge and further explains that SPRINT are used to more than just assembly instructions, since it is also a supply system that makes sure the right parts are at the right stations at a given time. Therefore, a key requirement should be that there should be one dedicated system for assembly information (or at least, one dedicated interface) instead of having a system used for several things. If not, it is hard to develop proper instructions with sufficient information for the operators since there are several important factors to consider.

5.3 Individualized and dynamic information

One of the most essential factors identified in the results is the factor that the perceived value of the instructions is too low, mainly due to that the amount of information does not relate to the current experience level. Hence, this is leading to a lower usage of the instructions and consequently, quality problems and assembly errors. Enofe (2017) and Schwarzkopf (2017) argues also in their study that there exists a gap between the availability and usage of information, and therefore argues that the information provided in assembly instructions today do not fully satisfy the operators. As stated from the interviews: *"the instructions are too extensive for experienced operators and too poor for novices."* meaning the time period for when the level of information is sufficient is too short. Also, the majority of the operators argue for that the information needs are dependent on the experience level, and therefore changes. The Technology Manager further argues for the importance of all operators using the instructions provided since even experienced operators need information regarding e.g. changes. Based on the above reasoning, the assembly information should be individualized and dynamic, and hence stated as a focus area that needs to be emphasized in order to improve quality in manual assembly. Further explanation of this concept has been visualized based on the findings in Figure 11.

Further, this has also been emphasized by the other roles interviewed in this thesis. For example, the MTS argued for that in order to be able to improve the assembly information, one of the main factor is this dynamic information. There are many parameters that need to be addressed and the information, the extent of it and the content itself need to be based on e.g: frequency/volume, experience level, how the operator perceives information in the best way, changes since last time and quality. However, to be able to implement this kind of action, the assembly information system need to be redesigned from the ground. An example of such a system has been included in this thesis with the comparison with Volvo Penta in order to create a better understanding of how it could function. This system utilized the benefits with digitalization and allowed this dynamic information with information levels based on experience, different views and layouts, change notes, quality messages on frequent problem areas, images, text sizes etc. based on a personal log-in system. All the above mentioned functions have also been identified in the findings of this thesis and should hence be key requirements in a new development. The results experienced after implementing this information system in Volvo Penta further strengthen the relevance of the result of this thesis, since they reduced the amount of assembly errors with 50% and hence improved quality substantially. Also, changes have been more rapidly introduced, which according to both interviews with other roles (such as MTS and Director Process & IT) as well as theory (Hu, 2013; Oliinyk et al., 2015) are crucial in order to stay competitive on a more demanding market. In addition, the learning curves for new operators has been reduced radially, which has been stated in our thesis to be a large problem, both in terms of operator satisfaction as well as quality problems.

If utilizing a system like this, the possibility to store production data increases, which then can be used for further analysis, which has been brought up by the Director Process & IT as an essential factor for the future. Therefore, this should also be considered as a key functional requirement. As the complexity in manufacturing increasing, which is argued for by e.g. Mattsson, (2013) and Johansson (2016), it is crucial to meet this development with a proper system of handling information to further support the operators working in this environment, and hence authors such as Agrawala et al., (2003), Osvalder & Ulfvengren (2009), Rasmussen (1983), Inaba, Smillie & Parasons (2004), Li, Cassidy & Bromilow (2013) and Fast-Berglund & Mattsson (2017) all argue for the importance of emphasizing the way information are presented for operators to support them in their work. Especially the latter stress the importance of investigating and focus on individual differences and needs when developing information support to operators.

5.4 Structure and visualization

It is mentioned by operators in all three case factories that it is hard for new operators to understand the instructions and to know what to do with the information that is given. However, for Plant B and Plant C this is just an initial problem since most of the operators later state that the MONT system is clear and easy to follow, whilst operators in Plant A must learn to navigate in those unstructured and unclear instruction. Even though the operators in both Plant B and Plant C think that the system is sufficient, there is a difference in usage which is further explained by Enofe (2017) and Schwarzkopf (2017). It is described because of the location of the information, where in Plant C the information is in front of the operators which makes it easier to use, in contrary to Plant B where it is behind them. Through the interviews with operators, MTS and Director of Process & IT it has been stated that it would be beneficial to gather all information in one place and preferably also have it mobile. Then, it would be possible to have the information when needed as well as to use the necessary information for that moment. This can also be seen at Volvo Penta where they are able to, in their program Casat, click on a task to get more information if needed. This interaction is also argued for by the MTS to be required in the future to make it easier to navigate among all information, both for experienced and new operators. For that reason, key requirements for a new information system are to have it mobile, have all information at one place as well as to be able to interact to show the needed information (access/hide) in order to improve the assembly information, increase the usage and hence improve quality in manual assembly.

Several operators in Plant A describes the instructions as unstructured, messy or hard to understand. Problems such as too much text and numbers, work is not in sequence, the tasks can be divided and separated as well as that important information are not more emphasized or highlighted than repetitive and not as important information. Therefore, according to Rasmussen (1983) it is important to arrange the information to the cognitive processes of the operators, where the cognitive process is the process of becoming aware of information and process it, which also is emphasized by the Technology Manager. This is done through e.g. vision, memory and attention. The first step towards an instruction that is matched with the cognitive process is to find the best assembly sequence, that makes it easy to follow the instruction in the work and it also makes it easier to take in the information for operators (Agrawala et al., 2003). This is done in all case factories, however, not presented in the information in Plant A. The theory further stresses the fact that information should be clear and easy to follow but also that it should be accessible and easy to find, and therefore it should be presented cycle wise in a step-by-step manner, especially for new operators to increase the knowledge. In order to make the instructions clear, things like arrows, lines, colours and different size of text can be used to highlight things that are important or different between the different variants (Osvalder & Ulfvengren, 2009), which also has been stated by the operator as missing today. To make it easier for the operators to navigate in the instructions, Osvalder & Ulfvengren (2009) suggest that a uniform design is used to ease the understanding of them. DFIP supports the theory from other authors but also adds that in order to make good instructions, there is a need of analyzing tasks depending on individual needs and differences as well (Fast-Berglund & Mattsson, 2017). This include to analyze if there are any physical conditions that needs to be taken into consideration, but also to analyze individual requests and to meet these requests if possible.

It has been done by another information system that has been used for comparison in Volvo Penta. In this system, it is possible for the operators to make own adjustments of the instructions. They are allowed to decide how much information that they want, how big the text is going to be and how big the pictures are. Everything is saved on their login so that everyone can save the settings and have the same on all stations where they are working. All information is also showed step-by-step and operators either have to push a button, which can be done by both hand or foot, in order to continue in the instructions and this strengthens the claims made by the theory. Consequently, additional key requirements for a future information system should emphasize the above mentioned factors in order to improve the structure and visualization of the instructions. For example, the information should in a clear way show differences and important tasks, show tasks in sequence, should be created to look the same, be presented step-by-step and there should be a possibility for the operators to make own small adjustments to the instructions which will ease the visualization and support the cognitive process.

5.5 Opportunities for standardization and implications

Based on the analysis and findings presented in the results as well as the thoughts discussed in the sections above, a possibility of working more towards standardization arises, which has been the overall purpose of this thesis. As described, Volvo has worked with acquisitions as a growth strategy, leading to diversity and are now focusing on standardization across plants and countries in order to utilize synergetic effects, which has been supported by e.g. Director Process & IT. The results in this thesis can be the basis for further work to create a new standardized assembly information system based on the true information needs from operators, by solving the problem areas and simultaneously addressing the focus areas to improve the assembly information and hence the quality in manual assembly. This new system would both contribute to standardized work in the preparation process as well as foster and facilitate standardized work in production by better support to operators, which has been identified in the thesis as a problem today. Although standardization can help manage the extensive product variety and product range that been built up within Volvo Group and thus manage productivity and cost (Liker & Meier, 2006; Fisher & Ittner, 1999) it is crucial to still emphasize on the balance with local adaptations to satisfy local markets and employees globally within the organization (Fisher, Jain, & MacDuffie, 1995). Further, the standardization should not be seen as one, rigid, and best way of working, however, it is needed in order to create an environment for further continuous improvement, which has been problematic today with the diverse and various different assembly information systems (Liker & Meier, 2006). Also, it is important to continue with the successful participation felt by the operators when developing and updating new instructions to be sustainable in the long-term and to encourage self-management in the teams, which is supported by e.g. Marksberry, Vu & Hordusky (2011), Adler et al. (2009) and Adler (1993).

5.6 Future research

To implement and utilize the findings in this thesis, more emphasis need to be addressed on further work and research. Practically, more work towards developing the requirements for a new developed assembly information system need to be conducted to decide both functional and nonfunctional requirements to understand how the new information system could function in the future. After this, a test pilot should be developed to test the function in industry to validate and adjust to achieve highest possible outcome. Lastly, the development of the final system can be initiated and consequently be implemented to be able to utilize all the benefits. Regarding the theoretical aspect of this thesis, more research towards how assembly information influence operations, quality and productivity should be emphasized as well as more in-depth studies on how an information system like this should function to manage product variety in the future, since the business environment moving towards more mass-customization. Also, it would be interesting to investigate the information need in additional environments, in terms of more cases with a more global or broader perspective to capture the need throughout different kind of organizations and environments.

5.7 Research quality

This thesis has focused on investigating the topic of information needs in order to improve the assembly information and hence the quality in manual assembly at Volvo Group Trucks Operations. The thesis has been based on a multiple case study with the purpose of study more than one case to broaden the scope, add more theoretical relevance as well as adding the ability to generalize the results in additional environments than just one. However, this topic need even further emphasis and in-depth cases to fully be able to generalize the findings into additional environments (Bryman & Bell, 2015).

Further, the thesis has used triangulation (Bryman & Bell, 2015) by using several data sources (interviews, literature study and comparison) to ensure the quality of the results as well as increase the comprehensive understanding regarding the topic. The thesis has been based on a qualitative research strategy, primarily focusing on interviews. One of the main benefits with the qualitative is the possibility of doing an in-depth study in a social setting and understand processes and peoples' knowledge and opinions, which has been of utmost importance in this thesis (Denzin & Lincoln, 2000). However, the results could have been even further strengthened by either conducting a mix-method study or adding a quantitative study with this thesis as foundation to open the possibility for comparing the qualitative data with quantitative data (Bryman & Bell, 2015).

The main data collection method of this thesis has been, as described before, interviews. The interviews have primarily been conducted with operators, however, also with additional roles in the organizations in order to collect data from different levels and consequently add new perspectives. The thesis used the semi-structured method for interviewing, which has been successful since the interviewees at several times added new perspectives not initially considered. The interviews have been conducted in the same way between all the operators and all the engineering roles respectively to ensure the quality of the collected data. Also, recordings of all interviews have been gathered and then used to further ensure the quality as well as that the correct data has been gathered from the interviews. Although, it would be interesting to interview even further engineering roles to see if the additional perspectives could contribute further to the results, however, due to time constraints this has not been possible in this thesis. In the other main data collection, literature study, the aim has been to collect and utilize a broad theoretical foundation with several authors on each topic to further strengthen the quality.

6. Conclusion

The aim of the thesis has been to assess the information needs in manual assembly that potentially could lead to improved assembly information and hence improved quality in manual assembly at Volvo Group Trucks Operations. The information needs can be divided into two main areas, problem areas of working methods and focus areas for improvements, which have been identified and developed in this thesis. Both areas are crucial to address to improve as well as sustain the improvement on a long-term basis, where the problem areas can be seen as the enablers and the focus areas as the drivers of the improved assembly information.

The identified problem areas have been identified to consider: *Instruction errors, Updates of instructions, Work training* and *Feedback and follow-up* and are vital to emphasize to support the processes and working methods around the assembly information. The developed focus areas consider: *Assembly information match, Individualized and dynamic information* and *Structure and visualization* and are also essential to stress in order to improve the assembly information, increase the usage of instructions by ensuring the usage value and hence improve the quality in manual assembly.

The result of this thesis consequently indicates an urge for continued work in the area, since a substantial improvement potential to improve quality in manual assembly in environments with high product variety has been identified. This thesis contributes with a direction for the future, based on the information needs in manual assembly, especially in terms of current problem areas and focus areas for improvement. Also, the thesis adds perspectives of how the findings could enhance and facilitate standardization as well as suggestions regarding requirement areas for a future developed assembly information system. Finally, the profit for organizations from this result can be used to further establish, maintain or increase their competitive advantage by better management of e.g. product variety, cost, quality and productivity in manual assembly, which is crucial to address the more demanding and rapidly changing business environment.

References

Adler, P. S. (1993). Time-and-motion regained. *Harvard Business Review*, 71(1), 97-108.

Adler, P. S., Benner, M., Brunner, D. J., MacDuffie, J. P., Osono, E., Staats, B. R., & Winter, S. G. (2009). Perspectives on the productivity dilemma. *Journal of Operations Management*, 27(2), 99-113.

Agrawala, M., Phan, D., Heiser, J., Haymaker, J., Klingner, J., Hanrahan, P. & Tversky, B. (2003), Designing effective step-by-step assembly instructions, *ACM Transactions on Graphics*, 22, 3, 828.

Bergman, B. & Klefsjö, B. (2010), *Quality from customer needs to customer satisfaction*, 3rd edn, Studentlitteratur, Lund.

Bryman, A., & Bell, E., *Business Research Methods*. Oxford University Press, 4 ed., 2015

Chung, L., Nixon, B., Yu, E. and Mylopoulos, J. (2013). *Non-functional Requirements in Software Engineering*. 1st ed. Springer-Verlag New York Inc.

Clarke, C. (2005). *Automotive production systems and standardisation*. 1st ed. Heidelberg [u.a.]: Physica-Verl.

Clark, R.C., Nguyen, F., Sweller, J. (2006), *Efficiency in learning: evidence-based guidelines to manage cognitive load*, Pfeiffer, San Francisco, Calif

Delin, F., & Jansson, S. (2015). *Process for preparing work instructions: A multiple case study at Volvo Group Trucks Operations*. Linköping University, Sweden. Retrieved from http://www.diva-portal.org/smash/record.jsf?pid=diva2:817356&dswid=4818

Denzin, N. and Lincoln, Y. (2000). *Handbook of qualitative research*. 2nd ed. Thousand Oaks: Sage.

Easterby-Smith, M., Thorpe, R. and Jackson, P. (2012). *Management research*. 1st ed. London: Sage.

Egaña, M., Kamp, B., & Errasti, E. (2013). Current Trends in International Operations. In Global Production Networks (pp. 1–34). *CRC Press*. http://doi.org/10.1201/b13753-2

ElMaraghy, H., Schuh, G., ElMaraghy, W., Piller, F., Schönsleben, P., Tseng, M. and Bernard, A. (2013). Product variety management. *CIRP Annals - Manufacturing Technology*, 62(2), pp.629-652.

Enofe, M. (2017). *Data Management In An Operational Context: A study at Volvo Group Trucks Operations.* Lund University School of Economics and Management, Sweden.

Fast-Berglund, Å. and Mattsson, S. (2017). *Smart Automation – metoder för slutmontering*. 1st ed. Gothenburg: Studentlitteratur.

Fisher, M., Jain, A., & MacDuffie, J. P. (1995). *Strategies for Product Variety: Lessons from the Auto Industry*. In E. Bowman & B. Kogut (Eds.), Redesigning the Firm (1st ed., pp. 116–154). Oxford University Press.

Fisher, M. and Ittner, C. (1999). The Impact of Product Variety on Automobile Assembly Operations: Empirical Evidence and Simulation Analysis. *Management Science*, 45(6), pp.771-786.

Fässberg, T., & Fasth, Å. (2011). *Cognitive automation in assembly systems for mass customization.* In Proceedings of the 4th Swedish Production Symposium (SPS).

Ganier, F. (2004), Factors affecting the processing of procedural instructions: implications for document design, *IEEE Transactions on Professional Communication,* 47, 1, 15-26.

Hu, S. (2013). Evolving Paradigms of Manufacturing: From Mass Production to Mass Customization and Personalization. *Procedia CIRP*, 7, pp.3-8.

Hull, E., Jackson, K. and Dick, J. (2011). *Requirements engineering*. 3rd ed. London: Springer.

Inaba, K., Smillie, R. & Parasons, S.O. (2004), *Guidelines for developing instructions,* CRC Press Inc, New York; London.

Johansson, P. (2016) *Challenges in Global Multi-Variant Serial Production - A Study of Manufacturing Engineering Processes*. Göteborg : Chalmers University of Technology (Research series from Chalmers University of Technology, Department of Product and Production Development: report, nr: 101).

Johansson, P., Mattsson, S., Moestam, L. och Fast-Berglund, Å. (2016) *Multi-Variant Truck Production - Product Variety and its Impact on Production Quality in Manual Assembly*.

Kotter, J.P and Schlesinger, L.A , "Choosing Strategies for Change" *Harvard Business School Press*, Boston, MA, July-August, 2008.

Lander, E. & Liker, J. K. (2007) The Toyota Production System and art: making highly customized and creative products the Toyota way, *International Journal of Production Research*, 45:16, 3681-3698, DOI: 10.1080/00207540701223519

Li, D., Cassidy,T., Bromilow, D. (2013) *The Design of Product Instructions*, licensee InTech, 101-114, Leeds

Liker, J. K. and Meier, D. (2006). *"The Toyota Way Fieldbook: A Practical Guide for Implementing Toyota's 4Ps"*. New York, McGraw-Hill.

Marksberry, P., Vu, D. and Hordusky, B. (2011). A quantitative investigation of Toyota's approach in teaching standardised work. *International Journal of Productivity and Quality Management*, 7(2), p.148.

Mattsson, S. (2013). *What is perceived as complex in final assembly? - To define, measure and manage production complexity.* Chalmers University of Technology. Retrieved from http://publications.lib.chalmers.se/publication/180925-what-is-perceived-as- complex-in-final-assembly

Oliinyk, O., Petersen, K., Schoelzke, M., Becker, M. and Schneickert, S. (2015). Structuring automotive product lines and feature models: an exploratory study at Opel. *Requirements Engineering*, 22(1), pp.105-135.

Osvalder, A.-L. & Ulfvengren, P., (2009). *Human-technology systems.* in M. Bohgard, a.o. red. Work and technology on human terms, 339-461. Prevent, Stockholm.

Palmer, B. (2004). *Making Change Work: Practical Tools for Overcoming Human Resistance to Change*. Milwaukee, Wisconsin: American Society for Quality, Quality Press.

Rasmussen, J. (1983). Skills, Rules, Knowledge, Signals, Signs and Symbols and other Distinctions Human Performance Models. *IEEE Transactions on Man, Systems and Cybernetics*, 257-266.

Schwarzkopf, M. (2017). *Data Management In An Operational Context.* Technische Universität Braunschweig, Germany.

Volvo Group 2016. (2016). [PDF Presentation] Volvo Group Headquarters. Available at: http://www.volvogroup.com/SiteCollectionDocuments/VGHQ/Volvo%20Group/Volvo%20Group/Presentations/Volvo%20Group%20presentation%202016%20English.pdf [Accessed 20 Jan. 2017].

Womack, J. P., Jones, D. T., & Roos, D. (1990). *The Machine that Changed the World*. Simon and Schuster.

Appendices

Appendix A - Comparison with Volvo Penta

During this thesis, a comparison at another business unit (Volvo Penta) and their plant in Vara has been conducted to enhance the understanding as well as study how a newly implemented information system functions and contributes to improved quality. Volvo Penta is a part of the Volvo Group and operates in an environment with high demands and customer specific products, where they develop and manufacture world-leading engines for the marine and industrial sector. Also, they operate in a demanding environment with rapid changes, which leads to a lot of changes in product and processes. They have for the past five years developed a new information system in terms of preparation and instructions together with MVV Information Technology, an IT-consultancy firm. The reason for developing this system have been to be able to handle the product variation in production efficiently with less quality problems.

The system is called Casat and is a modern system that utilizes the benefits of digitalization. The system allows for dynamic instructions to the operator based on their individual needs and choices. The operator can decide views, the amount of information that are presented, text size, images etc. based on experience level and are being stored to their personal login profile. This ensures the value for each operator irrespectively of experience level, and reduced the risk of not using the instruction and thus miss important changes and unusual variants.

The system is able to notify the operator of change orders e.g. changed material, changed assembly process etc. in order to secure that operators are getting the information. The changes are added by the engineers and can be implemented instantly in the system. The operator then has the choice to continue to get this information until the operator approves that the new instructions are understood. In addition, similar notifications can be added on critical activities to address frequent quality problems in order to notify the operation to secure these activities for a certain time period.

The information that is provided is selected and only focused on the information that the operator needs and not more, where the focus questions to answer are what, where, how and why to perform certain tasks. The work is described in sequence and the operator approves each line after conducting the specific activity, then the system presents the next task. However, the operator can interact through touchscreens and thus are able to go back or forth in the sequence. Through this interaction, the operator is also able to open additional information if needed e.g. more information about changes, make the images larger, get information why something is important etc. In this system, it is also possible to add activities that need to be performed to continue the cycle, e.g. scanning items and tool-based activities.

The result of this implementation has been a reduction of assembly errors of approximately 50% and hence improved quality, changes are now more rapidly introduced without problems, substantial reduction of needed learning time for new operators, more structured data that can be used for further analysis, higher operator satisfaction and more communication and cooperation between product development and operations.

Appendix B - Interview data from other roles in operations

In this chapter, the results from the additional relevant roles in operations at Volvo GTO are presented. These interviews have been conducted with personnel in higher, more knowledge-based and long-term positions, hence, the results are more focused towards future improvement potential in a broader sense as well as issues that need to be emphasized in an improved assembly information system and assembly instructions.

Manufacturing Technology Specialist

The Manufacturing Technology Specialist (MTS) role is higher up in the organization and hence work with more long-term and strategical projects, emphasizing future technology. The data from this interview has been structured in five different categories; *System and change, Dynamic instructions and its information, Education and training, Quality* and *Visualization and interaction*.

System and change

One of the biggest challenges and important factor are the development of instructions. The program and systems of today are not created to be flexible and adaptable to changes, but rather to find one best way and continue with that way. However, the business environment is going towards more customized and rapid changes, which is crucial for the future to build in the systems. Already today there is a need to change between stations and instructions, rebalance or change in another way, however, it is too time-consuming and it need to be faster, more flexible and easier. In order to keep up with the business environment and the customers, there is a need to utilize our personnel in the best way, by being flexible, rebalance, change tact time and/or change assembly activities in order to fit the needs.

Dynamic instructions and its information

Another challenge and important factor is that there is too much information, text and numbers on the instructions today and it is the same for everyone. However, it is a lot of parameters that varies dependent on the operators and their experience level, how they perceive in the best way, the activities on different stations, product range, quality issues, critical stations etc. For example, one station can have 5 respectively 30 variants, the operator can have worked at that station for 4 weeks respectively 10 years and the volume of the product can vary from 10-20 per day to 1 every sixth month. It is natural that the new operator need more step-by-step information and the more experienced operator don't use the instructions in the same way, however, they still need information about changes or low-volume products etc. So, the information need to be individual and dynamic based on e.g. the following factors:

- How often the specific variant is being produced (high/low yearly volume, then operators need different amount of support)
- Experience level of the operator (lead to different level of information)
- How the operator perceives information and prefer to see the information (different views, layouts, symbols, text, pictures, even culture since we perceive information in different ways as well as how we learn in the most efficient way)
- Changes since last time the particular operator built this product
- Quality (if a frequent quality problem is notified, then increase the frequency of information/signals to support the operators for that particular activity. Also add more

quality assurance activities and information to new operators and consequently remove with experience level to be more efficient)

Education and training

There is a need for better education and training of operators, especially in terms of off-line training on training stations so the operators are better prepared with higher level of knowledge before starting on-line. However, it is hard to get all the variants in the training period, since it can take 3-6 month before the plant need to build it. Then more pictures and short video can be used in the training session, so the operator can learn how the work should be performed in a better way. The personnel also need to be trained to be able to use the future information systems and digital tools. Important that they own their instructions and way of working, then in the future they need to understand how to change and work in this new environment.

Quality

The balance between quality assurance in the line and being too rigid are essential. The goal is to secure the quality but without removing to much of the responsibility and knowledge from the operators. Today, the operators need to press a button to move on to the next activity on some of the tasks, which takes a few seconds of pure waste in terms of movement and time from the station to the screen. In total, there are approximately hundreds of buttons pushes if a product is followed throughout the flow. Important to find better ways of securing and to be more portable and to have this kind of activities and information at hand.

Visualization and interaction

The most important in this topic is that information that is not needed at the current moment should not be shown. If the operator knows where the part should be assembled, the system does not need to show. But when the operator needs help, is should be easy to interact by e.g. touching the screen, use the voice or even that the system see when the operator need information (e.g. lower work-pace than normal or stop in work-pace) then the relevant information should be identified and provided to support. It can be done through screens, smart glasses, hologram, projections on the workpiece or any other technology from now or in the future. However, this demands a whole new information system, since it would be time-consuming today and the changes and development of instructions would take an extensive amount of time and not be worth it. It demands information from many different sources today, but the goal would be to have a large databank where the relevant information could be collected and presented based on that the need is. Further, it is important to study how the operators perceive information in order to be able to create efficient information systems and instructions that are easy to use and understand with a proper user-interface.

Technology Manager

According to the Technology Manager, the operator has all the information they need to be able to successfully assemble the product. This person is working with updating and creating instructions and are allowed to add/change pictures, control all the tools and add/change/remove different assembly activities. The operators are involved in the development and updating of instructions if problems or errors occur by submitting feedback to production technicians or group leaders. This feedback is then investigated with different stakeholders if it is feasible and it is an improvement in terms of ergonomics, quality, efficiency or another aspect. A lot of this feedback are considered but the hard part is that all the operator need to agree on the change, since all the operators are presented with the same instructions. Would be better if the instructions are more individual and dynamic so it is possible to tailor it so it fits the particular operator since experience level and technical knowledge varying. There are also a lot of changes in the information such as changes in components, activities, balance and the assembly process, and it is therefore important for experienced operator to read the instructions to notice these changes. However, the risk today is that they miss these changes since they do not use the instructions in that extent.

One of the biggest issues is that the system is quite inflexible and rigid. It demands to work in a certain pattern even if it is not the best way, making it hard and time-consuming to change. Also, some of the changes takes 2-3 days before it “hits” in the system. Another issue is that the instructions are sometimes not perceived as sufficient and clear from the operators. One big improvement where they lack today according to the technology manager is that the operator need to be educated and trained in a larger extent, both initially as well as continuously. There is a method called four-step-method which should facilitate standardized work. They also have certain operators as educators. Further, the information in the instructions need to be updated to truly fit the needs of the operators, since information today are unnecessary. Important information such as critical activities, frequent quality issues need to be highlighted for the operators in order to secure. The why-factor is also important to both educate but also to build in the information system (instruction). Another problem is that if something is done wrong in the preparation, there are no system that control and alert, which creates the risk of develop instructions with errors and then assemble the product wrong. Would be good with e.g. some kind of feedback or alert when the preparation does not match the number of components on this product. Generally, they have seen that when the cycle time are decreased, having less work on each station and less variation in the work, the quality is being increased. Finally, the technology manager means that today when is it possible for the operators to send the product away before the tact time, the time for adjustments and quality check can be neglected, in contrary to if the line is automatically send to the next station when the tact has been finished.

Production technicians

All the production technicians in Plant A agree that the instructions have become better overall. It has been only a couple of years ago since they started so use SOP’s and sequence sheets, which is mostly used when new operators are trained or when an operator have been away from that station for a while and have to refresh its knowledge. They feel that these instructions are good and can help the operators to gain the knowledge that they need to perform their work. These instructions are supposed to support the SPRINT instructions and therefore allow them to be shorter and manageable when working, but the production technicians all mention that SPRINT today is hard to interpret, especially for new operators. It is given by the interviews that the production technicians cannot decide what information that should be included in the SPRINT instruction, but they are allowed to hide some information, add comments and pictures as well as to change the order of the work. They also raise the problem with not being able to correct errors in SPRINT themselves, they can only leave a request for change and then create a temporary instruction that is used until the error has been corrected. In order for the production engineers to find errors they need the chassis number, CI-number and variant strings, this is often provided by the operators in the feedback. Also. there is a three-week freeze time on orders (i.e. and therefore also on instructions), leading to that the SPRINT instructions are locked for three weeks due to that the SPRINT system also functions as a supply system. This is a problem because then they must create temporary instructions until the changes have been made, and this makes the system more rigid and not as agile that is wanted and needed.

It is mentioned that Volvo evaluates the possibility to introduce screens at the stations where the instructions are displayed and there is a possibility to interact with these screens to be able to see more or less information, which would make it possible to gather different kinds of instructions in one place. This would make it easier to include pictures in the instructions which is something that could improve the quality of the instructions. It would also make it easier for the production technicians to update the instructions and for the updates to be available rapidly. This would also ease the possibility of highlighting critical operations and to highlight special trucks, so that the operators know that there is something that is supposed to be different with that truck. According to the production technicians, there is also a need for more education before a new operator start at the line since they need to understand how to read the instructions due to the substantial product variety. They also think that the training period should be longer and more standardized to make it easier for the new operator to acquire the right and necessary knowledge.

The perception of the instructions in Plant C today is that they are good but can contain some unnecessary information, which the production technicians are not able to affect since that information is gathered from other systems they cannot influence. Further, this inability to change information and only use what is necessary is seen as a big drawback of this system. Although, production technicians are allowed to add pictures, hide text and add descriptive comments which is the positive part of this system. The operators in Plant C are helpful when it comes to updating instructions and finding errors, they hand in a lot of suggestions and a lot of them is implemented. However, some of them is not possible to implement due to the system or to the work itself.

Today there are not any problems in the production that are directly connected with the MONT instructions, since most of the tools and hand scanners are connected to MONT is it hard to make errors. But one thing that can be a problem for the operators, especially for the new, is that the language in the instructions can be hard to understand and written in a too technical way meaning that they are more fitted for technicians than operators. It is mentioned that all the aids and connected tools in the production have reduced the responsibility of the operators which can create problems for the operator when it comes to product knowledge and general understanding of their work. It should be more focus on strengthen the operators and give them responsibility in order to create commitment to their work, which could reduce the quality problems. Another way is to put more focus on the education of new operators, which is insufficient today and the quality of it depends on the person that teaches.

Local Technology Specialist

Since the Local Technology Specialist (LTS) also works as a production technician in Plant A, a lot of the thoughts are already mentioned in the section above and thus supported by this person as well. However, the LTS brings up the fact that they have such a big number of variants that are being built at Plant A and the number of variants makes it harder to make instructions that are sufficient for all variants, due to fact that the operators need both different information and a different amount of information. Further, this also makes it hard for the production technicians to include pictures or cad-drawings in the instructions since there are a lot of different parts and for some variants it does not even exists any pictures or cad-drawings. Then, they must create these which takes a lot of time and is therefore not prioritized. As mentioned before there is a three-week waiting time before changes are made in the SPRINT, and the LTS further stress the fact that the SPRINT instruction rather can be seen more as a specification for the truck than a work instruction and in the future, they should therefore have a dedicated assembly instruction system. The LTS also discuss the sensitivity of the SPRINT, if something is changed or adjusted in the wrong way that article will not be delivered to the station that needs it. In the future, it must be easier for the production technicians to make changes in the instruction and find the information that is needed in them as well as give the production technicians the responsibility to make more changes themselves so that they do not have to wait for someone else to do it. In order for this to happen it is according to the LTS a need for better collaboration between the production technicians and the people in the product development department, because they need to understand how big problems different construction errors can create.

According to the LTS, the training of new operators is crucial for the success of the instructions and that further advocates a training area where operators can train before they start to work at the line. It is also stressed that all training should be standardized and performed in one way, to make sure that everyone gain the right knowledge for their work.

Director Process & IT

Volvo has for the last couple of years focusing on acquisitions and joint-ventures to expand and grow their organization and product range. This has created a substantial diversity, especially in terms of systems and processes, hence making it complex to improve on a large scale. The aim is now to structure, streamline and standardize the organization in order to be more efficient and open to future changes.

There are a number of focus areas, that will be vital in the future in terms of assembly instructions and IT-systems and they are *Mobility*, *Flexibility* and *Advanced Analytics*. The first factor, *Mobility*, means that information need to be portable and addressed where and when it is needed. Today, there are significant amount of waste both in time and movement when the instructions are stationed, either as a paper as in Plant A or digital screen as in Plant B and Plant C by moving back and forth between the workpiece and the information. To be more efficient, the mobility and portability will be crucial. This is important in all kind of manufacturing, however, it will be even more important in factories such as Plant A, where they build large and complex products. The stations are then physically large and there can be up to 20 operators on each station, which even further stress this issue since the need for movement are greater than in e.g. Plant B and Plant C, where one operator work on each station and workpiece. So, interesting technology such as smart pads and smart glasses are now investigated to see how it can contribute to the future assembly information system. The second factor, *Flexibility*, means that the system todays are too inflexible when performing changes (e.g. rebalancing, change of tact time or changes in product or process) and since the business environment will demand rapid changes and customization in the future, it is essential that the systems can handle and facilitate this. Finally, the third factor, *Advanced Analytics* (or Big data), aim at utilizing the extensive amount of data that already are gathered in the factories today such as data from tools, fixtures, product data, traceability etc. This data need to be collected, stored and be structured in order to make advanced analytical analysis, which will open up new opportunities to make significant improvements. This will greatly affect the way to manage e.g. operations, service market and sales. Lastly, another important issue to consider is to match the operators' information needs and the information presented in the instructions in the best way, which is not the case today.

Appendix C - Example of a SPRINT instruction

Below, an example of the SPRINT instruction is presented. These instructions can be several pages long dependent on the station and its work. Different activities are divided in sections and provides information regarding what components that need to be assembled and sometimes supported by text or comments.

Page XX of XX

Assembly Instruction Report Creation Date XXXX-XX-XX

ALL Montör 1 Avlastning AAL

Chassis Number	Sequence Number	Serial Number	Truck Type	Assembly Line
X XXXXX	XX-XX-X.XXX	XXXXXXXXXX	XX XXX X	XX

Hämta telfer — CI XXXXX

Kalla på telfer för chassilyft.

Rörpaket — CI XXXXX

Part	Qty	Description	C1	C2	Comment	Emb	UP
XXXXXXXX	1	RÖR CAB HEATER			Drag ej. Monteras på lösen, UTSIDA RAM	P3	XXXXX
XXXXXX	2	FLÄNSSKRUV M8*25				0	XXXXX
XXXXXX	2	FLÄNSLÅSMUTTER				0	XXXXX

Montera plugg till vattenrör (UEAS/EAS-SD) — CI XXXXX

Part	Qty	Description	C1	C2	Comment	Emb	UP
XXXXXXXX	1	ANSLUTNING			Monteras till pip på vattenrör	0	XXXXX

Avklammning höger ramsida — CI XXXXX

Klamma av befintliga klammor till ledningsmatta. Klammpunkt framför motorfäste till ändbalk.

Framför motorfästet skall kabelmattan placeras så nära insida ram som möjligt, detta för att undvika skav från startmotor.

Klamma av sidomarkeringskablage, fram och fram-mitten, höger sida. Klamma av höger klamma på konsol växellådsbalk.

Klamma av sidomarkerings-kablage, bak (MARKL-SR).

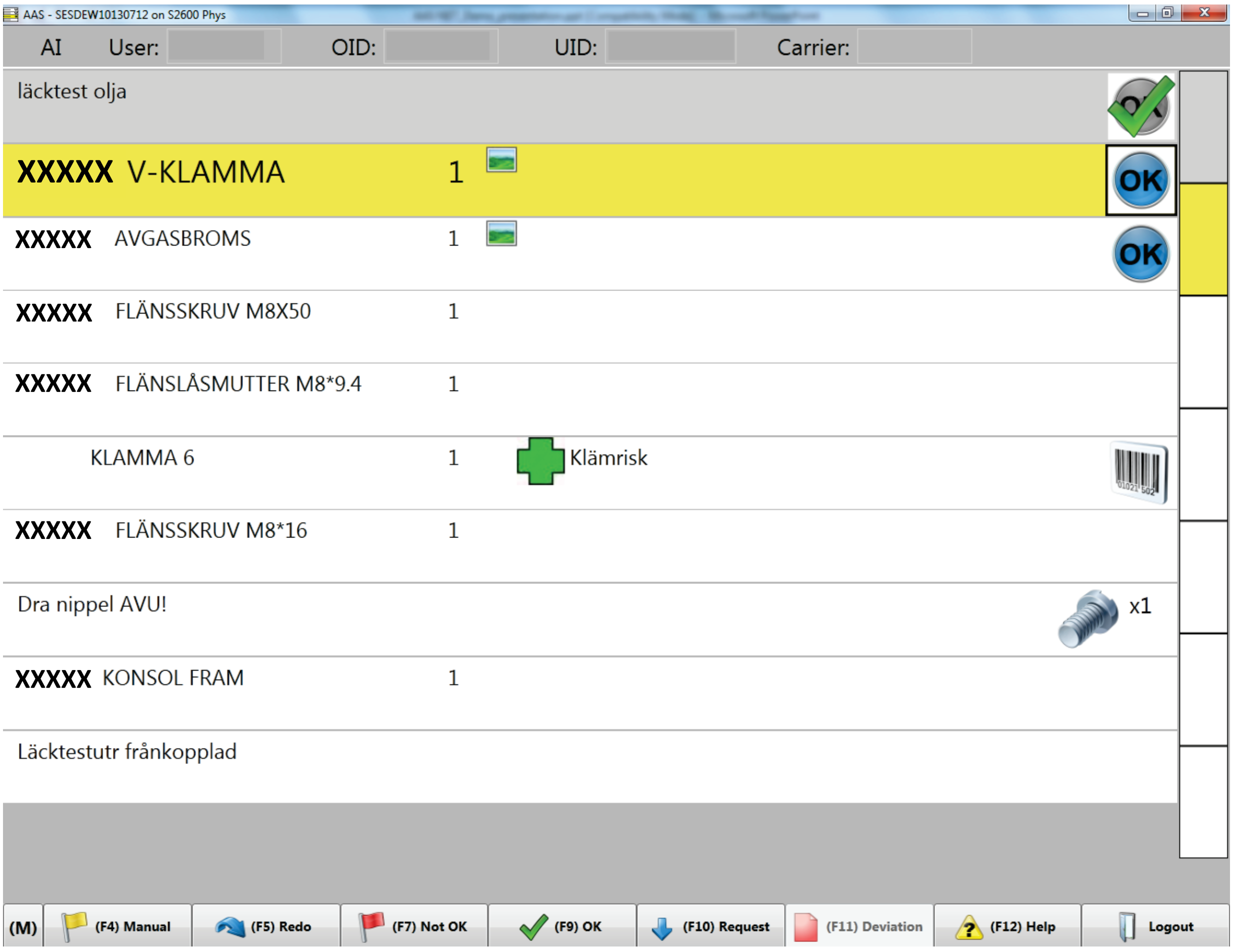
Klamma av sidomarkerings-kablage, överhäng (MARKL-SR).

Avlastning chassi, koppla lyftöglor. — CI XXXXX

Se Handhavandeinstruktion Chassilyft_vändare

Appendix D - Example of a MONT instruction

Below, an example of the MONT instruction is presented. Each row represents one task and can be connected with pictures, tools, scanners, buttons or other tools and are thus presented as a symbol. Also, there are possibilities to add symbols for safety precautions or quality. The work is presented in sequence and the current task is highlighted. In this interface, it is possible for the operator to e.g. reject or make quality assurance through a keyboard.



Appendix E - Interview guide for operators

Introduction

Thank you for participating in our study!

We are two master students from Chalmers that is currently doing our master thesis at Volvo GTO with the purpose to investigate how the information given at the assembly line today (especially the instructions for the manual assembly) is used, which demands there are for the future and how Volvo can enhance not only how the instructions are used but also the content of them. What we need from you and other participants in these interviews is data regarding the instructions used today, what the problems are but also what is good and what information that is important. This leads up to how could the instructions look like in the future, which demands should there be on the instructions in the future to make them work/function better. We are in this study going to focus on radical improvements, therefore do we want to urge you to think outside the box.

The participation in these interviews are of course going to be anonymous and the recordings will only be used by us, in order to ensure that no information is lost in the process. The data collection will consist of approximately 20-30 interviews, which later will be categorized and analyzed to find a base for improvement and a future wanted state.

If you do not have any questions are we ready to start!

- **Start recording (if consent is given) and state: name, date, time and place**

Questions

Demographics

1. Are you employed directly at Volvo or through a manning/staffing company?
2. How long have you been employed at the company?
3. How long have you been working at this station?
4. How long working experience do you have?
5. How old are you?
6. What level of general knowledge about technology do you have?
    a. Low/Medium/High
7. What kind of academic education do you have?
8. Did you get any kind of work related education when you started to work at this station?
    a. What kind? (Training facility, at station, instruction?

Main questions

Explain - introduction to main questions
Manual assembly is hard, especially with the high amount of variants that exists in the truck assembly, which makes this very interesting. Due to the high amount of variants it is hard to create good instructions which often leads to that the operators often thinks that they are unnecessary, hard to interpret or just time consuming to use, that can culminate in quality problem. Earlier studies show that approximately 60% of all quality problems are due to assembly errors, where the amount of variants and the design of the instructions have been pointed out as important factors. This is therefore something that we want to investigate further and how the instructions can support the operators in their work.

Explain focus and classification of that station
There are 13 stations included in our study (6 in Plant A, 4 in Plant B and 3 in Plant C), which are chosen to represent a common truck assembly with potential for improvement. These stations are divided into classifications depending on the work that is performed, which will create different focus for different stations and this **station ______**, which is **classified** as **________________**. **Explain the classification**

Show today's assembly instructions from the station that this interview concerns and use as a base for following questions

9. How do you know what to do when you perform an assembly in your daily work?
10. When you perform an assembly, do you follow any assembly instruction then?
11. Do you use it every day/daily?
    a. NO: How often do you use it?
12. For how long are you looking at it each time?
13. Do you consider your work at this station as difficult?
    a. In what way?
    b. Are the available assembly instructions helpful or do you trust your own experience?
14. Do you feel that there is enough time to use the assembly instructions?
15. What kind of information are you looking for in the instructions?
    a. How is this information later used?
    b. What kind of function does this information fill in your work?
16. Do you feel that the assembly instructions give you support through information?
    a. YES: In what way?
    b. NO: What do you miss?
17. Do you feel that the assembly instructions give you support through feedback during and after assembly operations?
    a. YES: In what way?
    b. NO: What do you miss?
18. Do you feel that the assembly instructions give you support in decision making?
    a. YES: In what way?
    b. NO: What do you miss?
19. Do you feel that the assembly instructions give you support when learning a new station?
    a. YES: In what way?
    b. NO: What do you miss?
20. Is there something else that you think is good or not so good with the assembly instructions with respect to ____________? (the classification of the station)
21. Do you have quality problems at this station?
    a. YES: What kind of problems is it that occurs? How do find out that they occur?
22. Do you feel that you can trust the assembly instructions used today?
    a. YES: If you have to choose between the assembly instructions or a colleague, who do you trust?
    b. NO: Why not? How do you handle this? Who do you trust instead?
23. Are you involved in the development of assembly instructions?
    a. YES: In what way?
    b. NO: Why not?
24. What kind of difference in information need exist depending on if you are new at the station in contrary to if you are more experienced?

Finally, we would like to show you a number of pictures:

**Shows pictures illustrating 3D instructions, Augmented Reality / Virtual Reality, Mobile picture instructions, Movie instructions and Audio instructions and asking respectively: **

25. How would the following influence your work?

Show instructions from other stations if there is time left (mont,sprint, saab etc)

26. What is it with these instructions that you think is good respectively not good?
27. Is it something you want to add that we have not covered?

Finished

We are done with the questions and will now analyze the data. As we said before you will be anonymous throughout the study and thank you for your participation!

Take a few minutes to go through the notes in order to ensure that we have covered everything and that they are organized properly

The questionnaire above has been translated from Swedish.

Appendix F - Interview guide for other roles

Introduction

Thank you for participating in our study!

We are two master students from Chalmers that is currently doing our master thesis at Volvo GTO with the purpose to investigate how the information given at the assembly line today (especially the instructions for the manual assembly) is used, which demands there are for the future and how Volvo can enhance not only how the instructions are used but also the content of them. What we need from you and other participants in these interviews is data regarding the instructions used today, what the problems are but also what is good and what information that is important. This leads up to how could the instructions look like in the future, which demands should there be on the instructions in the future to make them work/function better. We are in this study going to focus on radical improvements, therefore do we want to urge you to think outside the box.

The participation in these interviews are of course going to be anonymous and the recordings will only be used by us, in order to ensure that no information is lost in the process. The data collection will consist of approximately 20-30 interviews, which later will be categorized and analyzed to find a base for improvement and a future wanted state.

If you do not have any questions are we ready to start!

- **Start recording (if consent is given) and state: name, date, time and place**

Questions

Demographics

1. Are you employed directly at Volvo or through a consulting firm?
2. What kind of experience of Volvo do you have before your current position?
3. How long have you been employed at the company?
4. How long have you been working at this position?
5. How old are you?
6. What kind of academic education do you have?

Main questions

Explain - introduction to main questions

Manual assembly is hard, especially with the high amount of variants that exists in the truck assembly, which makes this very interesting. Due to the high amount of variants it is hard to create good instructions which often leads to that the operators often thinks that they are unnecessary, hard to interpret or just time consuming to use, that can culminate in quality problem. Earlier studies show that approximately 60% of all quality problems are due to assembly errors, where the amount of variants and the design of the instructions have been pointed out as important factors. This is therefore something that we want to investigate further and how the instructions can support the operators in their work.

7. Can you give an overall explanation of how sprint/mont is structured?
8. Can you explain what kind of support and assembly instructions that you have today for the operators?
9. What do you think of today's assembly instructions?
10. What are you allowed to do with the assembly instructions today?
11. How does it work when you develop new/ update assembly instructions?
12. Are the operators involved in the development of new assembly instructions?
13. How much of the feedback that you get from the operators are implemented?
    a. About sprint: Why does it take 3 weeks before the system is updated?
    b. About sprint: Why do you still use paper instructions?

    c. How often are the assembly instructions updated?
14. What kind of problems are connected to today's assembly instructions?
15. How much quality problems are there at the stations today?
    a. How could you reduce them?
    b. Could it be affected, positively, by changing the information given to the operators?
16. What kind of information is important, from your point of view, that the operators get when they are conducting their work?
17. In what kind of situations does the operators need more help?
18. In what way are the different kind of assembly instructions intended to be used when working?
19. Is there anything that would help the operators, but isn't used/exists today?
20. What kind of limits exists today?
21. How would you like to design the assembly instructions of the future, without today's restrictions?
    a. What should they contain?
    b. How should it be presented?
    c. How should the interaction between operator and technology look like?
    d. What is important in the future?
    e. How should digitalization help?
22. What is important for technicians when you work with the assembly instructions?
    a. Are there any problems that occur when develop or update the assembly instructions?
    b. Do you have any demands for the future?
23. What do you think of the trade-off between variants and quality? Is it affecting the development of the assembly instructions?
24. Is it something you want to add that we have not covered?

Finished

We are done with the questions and will now analyze the data. As we said before you will be anonymous throughout the study and thank you for your participation!

Take a few minutes to go through the notes in order to ensure that we have covered everything and that they are organized properly

This guide has been adjusted according to which role that has been interviewed based on the above questions. For Production technicians, LTS and Technology Manager the above guide has been used, for MTS more questions focused on strategically and long-term thought about the topic and finally, Director Process & IT focused more on IT, systems, future goals and assembly instructions. The questionnaire above has been translated from Swedish.

Appendix G - Data from interviews with operators

In this appendix, the data from the interviews with operators are presented. This first data is the results after the first grouping. The headings are the group name and the inputs on the left-hand side are the input brought up operators. The number then represent how many at each case that brought up that statement.

Instruction errors

	A	B	C
Are errors in the instructions, or they are out of date	6	3	2
Often wrong in the instructions for the "special" trucks	3		
Relying, most of the time, on the instuctions	7	3	4
A "do not care about the instructions" environment are created, due to sinking confidence for it	2		
Often wrong in the instructions when rebalancing of the stations are made	3		
The operators feel that they are involved in the development of instructions	11	6	5

Updating of the instructions

	A	B	C
It takes to long before errors are changed in Sprint, 3 weeks due to system constrains	5		
It takes to long before errors are changed in the instructions, which leads to a lot of temporary instructions	3	1	1
The operators have to learn when the Pick to Light is wrong since they can not change it without affecting another station	1		
The time between instruction updates are to long	4	2	1

Work difficulty

	A	B	C
The work is not hard	9	7	6
The work difficulty depends on which type of truck they are building (heavy/light)	2		

Individualized

	A	B	C
There is a difference in information needs between an experienced and a new operator	10	4	3
Much ot the information on the instructions are the same on every truck, so the infomation that is different between trucks should be highlighted so that it is not missed	8		
Should be able to log in at the station so that the instructions are individualized and so that information of changes, since the last time you worked there, is shown		3	1
The operators wants to be able to choose which information that they want to see	5	2	

Ergonomics

	A	B	C
The work is not designed to fit all (long/short..)			1

Paper instructions

	A	B	C
Waste with paper and time, needs much additional handling	1		
Match the right instructions with the right truck is done by hand, can lead to errors	4		

Feedback and follow- up

	A	B	C
Bad feedback on assembly errors		4	
Instructions are not followed and new instructions are not always adapted due to poor follow-up		2	

Feedback of work

	A	B	C
Pick to light and the screwdrivers gives good feedback	1	3	6
Thinks that it is to controlled today with e.g. pick to light, scanning		1	3
Want to have feedback for quality control, some kind of signal	9	6	
Mont gives good feedback and works as a quality check, not moving on if its not done		1	5
Only uses Mont because you need to, scan parts or push F9 to show that you have done certain operations		2	4

Information need	A	B	C
Only using specific parts of the information that can be found in the instuctions	10	3	4
Information of what articles that are needed for a operation is used	11	5	6
Chassinumber is used	8		
Information about truckt- or enginetype is used	3	1	
Information in the comments are used	2		
Information conserning quantities are used	8	1	1
Information about screw length is used	7		
Information of where something should be placed, its position, is used	11	3	4
Need real-time information	4	1	
Need more information about part positions, "where"	9	2	2
Need more information about the execution of a operation, "how"	12	2	1
Need to get more and better information about changes in the instruction	4	2	
Need more information about problems that can occur and how to solve them		1	1
Need more information about hidden assembly (e.g. holes)		1	
Need more information and explanation about the work and its operations to create knowledge for new operators	10	4	5
Would be good to be able to carry the information with you all the time, and scan important parts	7	6	5
Technical aids such as VR and 3D pictures, would be good to get a good combination of picture and text information (text=what, picture=how), and the work in right sequence	12	4	5
It would be good to have technical aids such as hologram in the future, easy to interact with			1
It is important that you only get the information that is necessary for that station	1	2	4

Use of instructions	A	B	C
Have no time to watch in the instructions when working on heavy variants	1	1	
Only use the instructions when I do not know what to do	5	1	2
It is important to read the instructions to not miss any changes, mostly material changes	2	3	
It is not enough time to read the whole instruction, only about specific things	9	2	4
Mostly using your own experience when assembling	11	6	5
The instructions (Sprint, Mont) is considered to be helpful to dubble check your work	8	2	3
Never/rarely use the instructions	4	4	
Uses Sprint/Mont (and PTL) on every truck/engine/gearbox	6	3	6
Uses Sprint/Mont (and PTL) at least once every day	3	1	1
Only look for a couple of seconds in the instructions when using them	10	6	6
SOP:s are frequently used		4	
Look for 20-60 seconds in the instructions when using them	2		

Pictures	A	B	C
Only want pictures on the critical work	5	3	1
Want pictures of the different hole patterns, for easier learning	9		
Pictures are good for quality control but also for understanding	9	4	1
Want more pictures on special variants to ease understanding	4		
Want pictures of how it should look like when your work is done at a station	3	2	3
Want screens that you can interact with	7		
Pictures today are unclear/ bad quality		2	3
The information is not adjusted to the technology that is used			1

Quality problems

	A	B	C
Assemble in the wrong hole pattern	2		
Component break due to assembly error	2		
Assemble the wrong screw (which type, length)	4		
Due to time constraints is there no time to check or adjust your work	2		
Easy to forget to assemble components or conduct elements	5	2	2
The most common errors are sloppy mistakes		3	2
Quality problems due to assembly error		3	1
The handling/use of PTL lamps can lead to quality errors		2	1
It is easy to redo operations and write rejects in Mont and it is important to keep		1	

Work training

	A	B	C
Get to train with the machines before starting at the line	5		
Trained at the line	11	6	6
The work is not standardized, everybody conduct the work differently	7	3	4
To start directly at the line makes it hard to create any knowledge, due to stress	3	2	1
A New operator has a longer learning curve due to shortcommings in the instructions	4		
Big variation of how the work training is conducted	7	2	3
Workers obtain different levels of knowledge due to different training	5	3	6
An experienced operator with a lot of knowledge should be the ones who train new people	3	2	4
A new operator need to learn how to read the instructions	3		1
Hard to know where to look for information since they have so many different kinds of instructions (SOP, VSS, Sprint/Mont)	2	2	
Today is overall understanding missing, what is happening before and after my station, and knowledge about the product	6	3	5
Should be a bigger focus on the person that you train		2	
Movies about the work could be good to use when you train new operators (look at critical moments and special products)	9	5	3

Structure and visualization of instructions

	A	B	C
The instructions (Sprint, Mont) are difficult to interpret for new operators	9	2	2
Sprint does not tell you were something should be mounted, only gives you a measure as description	1		
To much text and numbers in the instructions (Sprint, Mont) so it becomes hard to read and understand, a lot of unnecessary information	10	1	
Sprint and Mont only tells you "what" to do, nothing about "how"	6	1	
The reference system for length and counting the holes in the beams is bad, and hard to use	2		
Unclear numbering of beams: no1,1,2,3: where no1 is in the middle	1		
It is not always that Sprint follow the working sequence	3		
The instruction does not say anything of were in the working cycle you are	1		
The information that is important should be highlighted or placed first in the instruction	3		
Poor logic in Sprint, some information is divided and some is repeted	7		
The language in Sprint is to technical and sometimes it changes between Swedish and English	5		
The instructions should be more user friendly	4		
The information in Mont is clear, Mont gives you the information that you want, when you want it		1	4
The design of the kit trolley can be seen as a instruction, gives information of what to pick		2	
The ones who creates the instructions has no knowledge about the actual work, => bad instructions		1	

The data below is the result after the second grouping and hence more aggregated and has been the primary results used in the thesis.

Use of instructions

	A	B	C
Have no time to watch in the instructions when working on heavy variants	1	1	
Only use the instructions when I do not know what to do	5	1	2
It is important to read the instructions to not miss any changes, mostly material changes	2	3	
It is not enough time to read the whole instruction, only about specific things	9	2	4
Mostly using your own experience when assembling	11	6	5
The instructions (Sprint, Mont) is considered to be helpful to dubble check your work	8	2	3
Never/rarely use the instructions	4	4	
Uses Sprint/Mont (and PTL) on every truck/engine/gearbox	6	3	6
Uses Sprint/Mont (and PTL) at least once every day	3	1	1
Only look for a couple of seconds in the instructions when using them	10	6	6
SOP:s are frequently used		4	
Look for 20-60 seconds in the instructions when using them	2		
Waste with paper and time, needs much additional handling	1		

Quality problems

	A	B	C
Assemble in the wrong hole pattern	2		
Component break due to assembly error	2		
Assemble the wrong screw (which type, length)	4		
Due to time constraints is there no time to check or adjust your work	2		
Easy to forget to assemble components or conduct elements	5	2	2
The most common errors are sloppy mistakes		3	2
Quality problems due to assembly error		3	1
The handling/use of PTL lamps can lead to quality errors		2	1
It is easy to redo operations and write rejects in Mont and it is important to keep		1	
Match the right instructions with the right truck is done by hand, can lead to errors	4		

Work difficulty

	A	B	C
The work is not hard	9	7	6
The work difficulty depends on which type of truck they are building (heavy/light)	2		

Individualized

	A	B	C
There is a difference in information needs between an experienced and a new operator	10	4	3
Much ot the information on the instructions are the same on every truck, so the infomation that is different between trucks should be highlighted so that it is not missed	8		
Should be able to log in at the station so that the instructions are individualized and so that information of changes, since the last time you worked there, is shown		3	1
The operators wants to be able to choose which information that they want to see	5	2	

Instruction errors

	A	B	C
Are errors in the instructions, or they are out of date	6	3	2
Often wrong in the instructions for the "special" trucks	3		
Relying, most of the time, on the instuctions	7	3	4
A "do not care about the instructions" environment are created, due to sinking confidence for it	2		
Often wrong in the instructions when rebalancing of the stations are made	3		
The operators feel that they are involved in the development of instructions	11	6	5

Assembly information match	A	B	C
Only using specific parts of the information that can be found in the instuctions	10	3	4
Information of what articles that are needed for a operation is used	11	5	6
Chassinumber is used	8		
Information about truckt- or enginetype is used	3	1	
Information in the comments are used	2		
Information conserning quantities are used	8	1	1
Information about screw length is used	7		
Information of where something should be placed, its position, is used	11	3	4
Need real-time information	4	1	
Need more information about part positions, "where"	9	2	2
Need more information about the execution of a operation, "how"	12	2	1
Need to get more and better information about changes in the instruction	4	2	
Need more information about problems that can occur and how to solve them		1	1
Need more information about hidden assembly (e.g. holes)		1	
Need more information and explanation about the work and its operations to create knowledge for new operators	10	4	5
Would be good to be able to carry the information with you all the time, and scan important parts	7	6	5
Technical aids such as VR and 3D pictures, would be good to get a good combination of picture and text information (text=what, picture=how), and the work in right sequence	12	4	5
It would be good to have technical aids such as hologram in the future, easy to interact with			1
It is important that you only get the information that is necessary for that station	1	2	4
Only want pictures on the critical work	5	3	1
Want pictures of the different hole patterns, for easier learning	9		
Pictures are good for quality control but also for understanding	9	4	1
Want more pictures on special variants to ease understanding	4		
Want pictures of how it should look like when your work is done at a station	3	2	3
Want screens that you can interact with	7		
Pictures today are unclear/ bad quality		2	3
The information is not adjusted to the technology that is used			1
Pick to light and the screwdrivers gives good feedback	1	3	6
Thinks that it is to controlled today with e.g. pick to light, scanning		1	3
Want to have feedback for quality control, some kind of signal	9	6	
Mont gives good feedback and works as a quality check, not moving on if its not done		1	5
Only uses Mont because you need to, scan parts or push F9 to show that you have done certain operations		2	4

Structure and visualization of instructions	A	B	C
The instructions (Sprint, Mont) are difficult to interpret for new operators	9	2	2
Sprint does not tell you were something should be mounted, only gives you a measure as description	1		
To much text and numbers in the instructions (Sprint, Mont) so it becomes hard to read and understand, a lot of unnecessary information	10	1	
Sprint and Mont only tells you "what" to do, nothing about "how"	6	1	
The reference system for length and counting the holes in the beams is bad, and hard to use	2		
Unclear numbering of beams: no1,1,2,3: where no1 is in the middle	1		
It is not always that Sprint follow the working sequence	3		
The instruction does not say anything of were in the working cycle you are	1		
The information that is important should be highlighted or placed first in the instruction	3		
Poor logic in Sprint, some information is divided and some is repeted	7		
The language in Sprint is to technical and sometimes it changes between Swedish and English	5		
The instructions should be more user friendly	4		
The information in Mont is clear, Mont gives you the information that you want, when you want it		1	4
The design of the kit trolley can be seen as a instruction, gives information of what to pick		2	
The ones who creates the instructions has no knowledge about the actual work, => bad instructions		1	

Work training

	A	B	C
Get to train with the machines before starting at the line	5		
Trained at the line	11	6	6
The work is not standardized, everybody conduct the work differently	7	3	4
To start directly at the line makes it hard to create any knowledge, due to stress	3	2	1
A New operator has a longer learning curve due to shortcommings in the instructions	4		
Big variation of how the work training is conducted	7	2	3
Workers obtain different levels of knowledge due to different training	5	3	6
An experienced operator with a lot of knowledge should be the ones who train new people	3	2	4
A new operator need to learn how to read the instructions	3		1
Hard to know where to look for information since they have so many different kinds of instructions (SOP, VSS, Sprint/Mont)	2	2	
Today is overall understanding missing, what is happening before and after my station, and knowledge about the product	6	3	5
Should be a bigger focus on the person that you train		2	
Movies about the work could be good to use when you train new operators (look at critical moments and special products)	9	5	3

Updating of the instructions

	A	B	C
It takes to long before errors are changed in Sprint, 3 weeks due to system constrains	5		
It takes to long before errors are changed in the instructions, which leads to a lot of temporary instructions	3	1	1
The operators have to learn when the Pick to Light is wrong since they can not change it without affecting another station	1		
The time between instruction updates are to long	4	2	1

Feedback and follow- up

	A	B	C
Bad feedback on assembly errors		4	
Instructions are not followed and new instructions are not always adapted due to poor follow-up		2	